Canada: Geodetic Service

DEPARTMENT OF THE INTERIOR, CANADA

HON. SIR JAMES LOUGHEED, Minister — W. W. CORY, Deputy Minister

GEODETIC SURVEY OF CANADA

NOEL OGILVIE, Superintendent

ANNUAL REPORT

OF THE SUPERINTENDENT

OF THE

GEODETIC SURVEY OF CANADA

FOR THE

FISCAL YEAR ENDING MARCH 31, 1921

1920/21

OTTAWA,
THOMAS MULVEY
PRINTER TO THE KING'S MOST EXCELLENT MAJESTY
1921

PRESENTED

WITH THE COMPLIMENTS OF

THE SUPERINTENDENT

GEODETIC SURVEY OF CANADA

OTTAWA

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REPORT OF THE SUPERINTENDENT

OF THE

GEODETIC SURVEY OF CANADA

W. W. Cory, Esq., C.M.G.,
Deputy Minister of the Interior,
Ottawa.

Sir,—I have the honour to submit herewith my fourth annual report as Superintendent of the Geodetic Survey of Canada, for the fiscal year ending the 31st of March, 1921, showing in general the operations of this branch, together with more detailed reports of the engineers in charge of the various sections of the work.

During the fiscal year ending the 31st of March, 1921, the basic operations of the Geodetic Survey of Canada have been extended in accordance with our policy of supplying various departments of the Federal and Provincial Governments, municipalities, companies and private engineers with the geographic positions and precise elevations of points for the control of future surveys and for the correction and compilation of new editions of maps or charts. There has also been expansion of the general scheme at such points as local requirements have rendered necessary.

OUTLINE OF POLICY FOR THE BASIC OPERATIONS OF THE GEODETIC SURVEY OF CANADA

The basic operations referred to above are triangulation—primary and secondary—and precise levelling. The aim of the Geodetic Survey is the establishment of points based on the North American and on mean sea-level datums, which will be accessible for all major engineering and mapping projects.

A more extended statement of policy in regard to triangulation and precise levelling will show more clearly where further extensions will take place. Plans for the future are tentative and subject to change as the needs become clearer.

Triangulation Policy

The ultimate aim of the Geodetic Survey of Canada is to lay down one or more nets of primary triangulation extending from coast to coast, with branches from these nets along both coasts and at intervals in the interior. This programme will be worked out as the requirements demand. In addition, such nets of secondary triangulation will be laid down as will meet local demands.

As the triangulation progresses surveys of lesser degrees of accuracy are connected to it and thus finally geographic results over Canada can be moulded into one harmonious whole on a co-ordinated scheme and on a basis which gives the correct relation of one part to another.

Considerations which Influence Triangulation Policy.—Three considerations influence the extension of the primary triangulation: first, that all parts of the country shall be so accessible to primary triangulation that they can be reached without appreciable error by secondary triangulation based on the primary; this means that primary triangulation should ultimately be laid down to within 100 miles

of any part of the country as required; second, that topography shall be a governing factor in the route taken. This means that the most economical route shall be taken; third, that primary triangulation nets shall pass as near as possible to those sections of the country in which existing or future requirements are noted. Such sections include waterways, international and interprovincial boundaries, large cites, industrial and mining areas, etc.

Availability of the North American Datum.—With immediate demands for triangulation in parts of the country scattered from the Atlantic to the Pacific, it is fortunate for Canada that the primary triangulation of the United States Coast and Geodetic Survey, which has been in progress for over one hundred years, and which has been extended to the Canadian border at a number of points, has been available for the extension of our primary triangulation. This has enabled our primary triangulation to be carried on at the required points with the assurance that all such nets are based on the same geodetic datum, the North American datum, and will be free from gaps, offsets and overlaps where the different nets join. Perhaps a more important result is that final values of the geodetic positions of points may be issued at once, and that revisions of these positions are unnecessary.

Thus primary triangulation was commenced on the bay of Fundy in New Brunswick, at a point near Montreal, on lake Superior, and on the Pacific coast, and was based on the United States Coast and Geodetic Survey stations. Other United States nets are available for extension at three or four points on the 49th parallel along the south boundary of the western provinces.

Triangulation, Past and Future, Fits in with this Ultimate Aim.—The map at the back of this report shows the progress of the primary triangulation to date. Consulting this map, the tentative future extensions may be traced.

The net which was started in *the Montreal vicinity* has been extended eastward down the St. Lawrence and westward as far as lake Huron, thus covering the better settled portions of Ontario and Quebec and establishing geodetic positions along a large part of our great inland waterway.

This net will be extended eastward to the strait of Belle Isle and will be available as a basis for hydrographic charting, for future surveys of the Labrador-Quebec boundary and for projection of the North American datum to Newfoundland. In the west this net will be extended up Georgian bay and to lake Superior to join the Port Arthur net mentioned below. A branch of this net will be projected north to the Cobalt region and on to James bay.

From the *Bay of Fundy region* near St. Andrews, N.B., a primary net has been extended eastward along both sides of the bay of Fundy, thence eastward along Minas basin to Truro, N.S., southward to Halifax and eastward towards Sydney, N.S.

Projected work in this region consists of the extension of present nets to the Magdalen islands and if possible to Newfoundland, together with a secondary net around the south coast of Nova Scotia and on Prince Edward Island. A primary scheme is now in progress along the *east coast of New Brunswick* which will link up the Bay of Fundy operations with those of the gulf of St. Lawrence.

The United States Lake Survey triangulation on *lake Superior* has been extended to cover the Port Arthur vicinity, thence westward along the international boundary.

Future extensions of this net westward to lake of the Woods and to Winnipeg may be looked for.

In *Alberta* a reconnaissance survey for primary triangulation was made; in time this will become part of a general scheme of triangulation in the *Prairie Provinces.*

A fundamental part of this general scheme is to be started in 1921 by international co-operation between this Survey and the United States Coast and Geodetic Survey. Under this arrangement a primary triangulation net will be developed along the 49th parallel from lake of the Woods to the Pacific ocean. The eastern half

of this work will be done by this Survey and the western half by the United States Coast and Geodetic Survey. Thus, the cost to Canada of this necessary and fundamental piece of work will be cut in half through international co-operation. It will form the basis of our general programme in the West, which will include such north and south and east and west nets as are required.

Two east and west nets along the *Canadian Pacific* and *Canadian National railways* will ultimately connect the prairie triangulation with that on the Pacific coast.

The primary triangulation along the *Pacific coast* has been extended northward between Vancouver island and the mainland from the United States Coast and Geodetic Survey net to the south. A small primary net was laid down in the Prince Rupert vicinity to control the surveys of the international boundary between Alaska and British Columbia. This was done with primary triangulation accuracy so as to later form an integral part of the net along the British Columbia coast. The datum used was the Alaska coast datum, hence results will be revised when connection is made to the North American datum to the south.

The Pacific coast triangulation illustrates the cordial spirit of international co-operation which exists between the United States Coast and Geodetic Survey and the Geodetic Survey of Canada. The former organization is energetically carrying its primary triangulation northward along the United States Pacific coast to make the North American datum available for use by the Geodetic Survey of Canada. The Canadian Survey will carry this datum northward through its primary triangulation along the coast to the vicinity of Prince Rupert, where it will be again available for the United States survey which is carrying on primary triangulation along the coast of southeastern Alaska to the head of the Lynn canal. From this point the Geodetic Survey of Canada will carry the work *through the Yukon*, where it will again be available for the United States triangulation surveys of the interior of Alaska. This one instance is especially mentioned as being typical of the cordial relations which have existed between the two organizations, a relation which has been manifest on the many occasions on which their interests have been in common.

Secondary Triangulation.—Various secondary triangulation schemes have been based on the above primary nets in the vicinities of large cities and industrial areas. Such areas include *Halifax, N.S.; St. John, N.B.; Montreal, Que.; Toronto* and *London, Ont.;* and *Vancouver* and *New Westminster, B.C.* Other areas will be added to these as requirements demand.

Secondary triangulation nets will be employed to control the accuracy of surveys over limited areas or between primary triangulation nets or to project work for long distances where the cost of primary triangulation makes it at present inexpedient.

PRECISE LEVELLING POLICY

Precise levelling was pushed ahead energetically during the summer of 1920, operations being carried on in five of the provinces.

It becomes increasingly evident that there should be no slackening in this branch of the Survey's activities, as requests are constantly being received from Federal and Provincial Government offices, from railway companies, private engineering organizations and others, asking that accurately determined elevations be furnished them. In many cases the communications take the form of a request for descriptions and elevations of all bench-marks along some line of railway between certain points or for all precise elevations in some particular province or district. In many other cases the elevation is required for bench-marks in a city, town or village or for an isolated point in the country, to serve as an initial point for some engineering project. All these requests and the many appreciative letters received indicate that the work of the Survey is becoming better and more favourably known and that engineering organizations are quick to appreciate its practical value.

The only unfortunate feature is that the present state of advancement of the field work often allows only a partial compliance with many of the requests and in other cases the Survey is totally unable to furnish the information desired. This shows that the field work should be vigorously prosecuted year by year and an earnest effort made to overtake the demands of the public and as far as possible to forestall them. In planning the work to be undertaken it is the general policy to (*a*) comply with any requests for work in stated districts, (*b*) extend control levels into districts not at present served and thereby anticipate demands for the same, (*c*) run such trunk lines and connecting links as are required to strengthen the Dominion wide precise level net, and enable an adjustment to be made eventually which will fix the elevations of bench-marks in all parts of the country within very small limits of error.

RÉSUMÉ OF SEASON'S OPERATIONS

TRIANGULATION

British Columbia.—The primary triangulation on the coast of British Columbia was extended northward by three parties, a reconnaissance party, a station preparation party, and two angle measurement parties. The region at the north end of Vancouver island where the parties were working is specially unfavourable for primary triangulation on account of the prevalence of fog. This condition may be realized from the fact that a lighthouse on Triangle island, off the northern end of Vancouver island, has been abandoned, largely owing to the almost constant fog. A triangulation station on Cox island, close by, was occupied for four weeks during 1920, during which time readings were obtained on only three nights on account of fog.

From the north end of Vancouver island the triangulation follows the inside passage for about 125 miles, after which Hecate strait is *bridged* for a further 125 miles, triangulation stations occupying hills on the Queen Charlotte islands on the west of the strait and elevations on the mainland to the east.

Transportation on the coast is accomplished by means of the 65-foot launch "Metra." This boat has proved invaluable and quite suitable when working in the straits between Vancouver island and the mainland, where convenient shelter could be easily found, but doubtless, time will be lost owing to rough weather when the triangulation proceeds to bridge Hecate strait, which is from 35 to 80 miles wide. The report of the engineer in charge of operations on the British Columbia coast begins on page 32.

Alberta—Saskatchewan.—Starting from the primary net of the United States Coast and Geodetic Survey, which meets the international boundary at the boundary between Alberta and Saskatchewan, a reconnaissance survey for primary triangulation net was projected north to Medicine Hat, thence northwestward to within 40 miles of Calgary.

Some 125 miles of reconnaissance was laid down in about two months of the season, the remainder of the season being taken up with a general reconnaissance to size up the country so that all the factors which determine the best route to be taken by the triangulation might be given full consideration.

Since no primary triangulation had previously been attempted in Canada in this class of country, this work was to some extent an experiment to see whether any changes would be necessary in the reconnaissance methods which had proved successful in other parts of the country. It is believed that no special difficulties will be encountered, and indeed it is confidently hoped that progress on the prairies should be quicker than in some other parts of Canada.

Beginning on page 33 the report of the engineer in charge of this work will be found.

Ontario.—Reconnaissance, angular measurement of primary triangulation and city triangulation constituted the operations in Western Ontario during the season of 1920.

Triangulation had been discontinued in 1917 in this section and was recommenced in 1920, to obtain the benefit of certain towers which were still standing and so that the work might be carried to the shores of lake Huron and lake Erie at strategic points.

A triangulation system embracing the city of London and vicinity, based on the primary triangulation in that region, was completed during the season. The purpose of this net, in conjunction with a precise level net, was to control the accuracy of the city mapping of London, which is being done by the Geodetic Survey. The reports of the engineers engaged on triangulation in Ontario begin at pages 34, 35 and 36.

Quebec.—Triangulation operations in Quebec province were confined to the lower St. Lawrence river and gulf.

Reconnaissance for the selection of stations was carried down the gulf from Pointe des Monts to Anticosti island. Weather conditions on the gulf were quite favourable for reconnaissance and a successful season was experienced, about 13,000 square miles being covered and 23 stations selected. A base line was laid out near the west end of Anticosti island, which will be measured during the season of 1921.

On the south shore of the gulf, in Gaspé county, the banks are very high and sharp, the hills rising to heights of 1,000 to 2,000 feet within a couple of miles of the shore. Further back the Shicshock mountains make a very pretty sight when viewed from the gulf on a clear day. A tower building party was engaged during the season, building towers 20 to 50 feet high at the triangulation stations on the timber covered hills along the south shore.

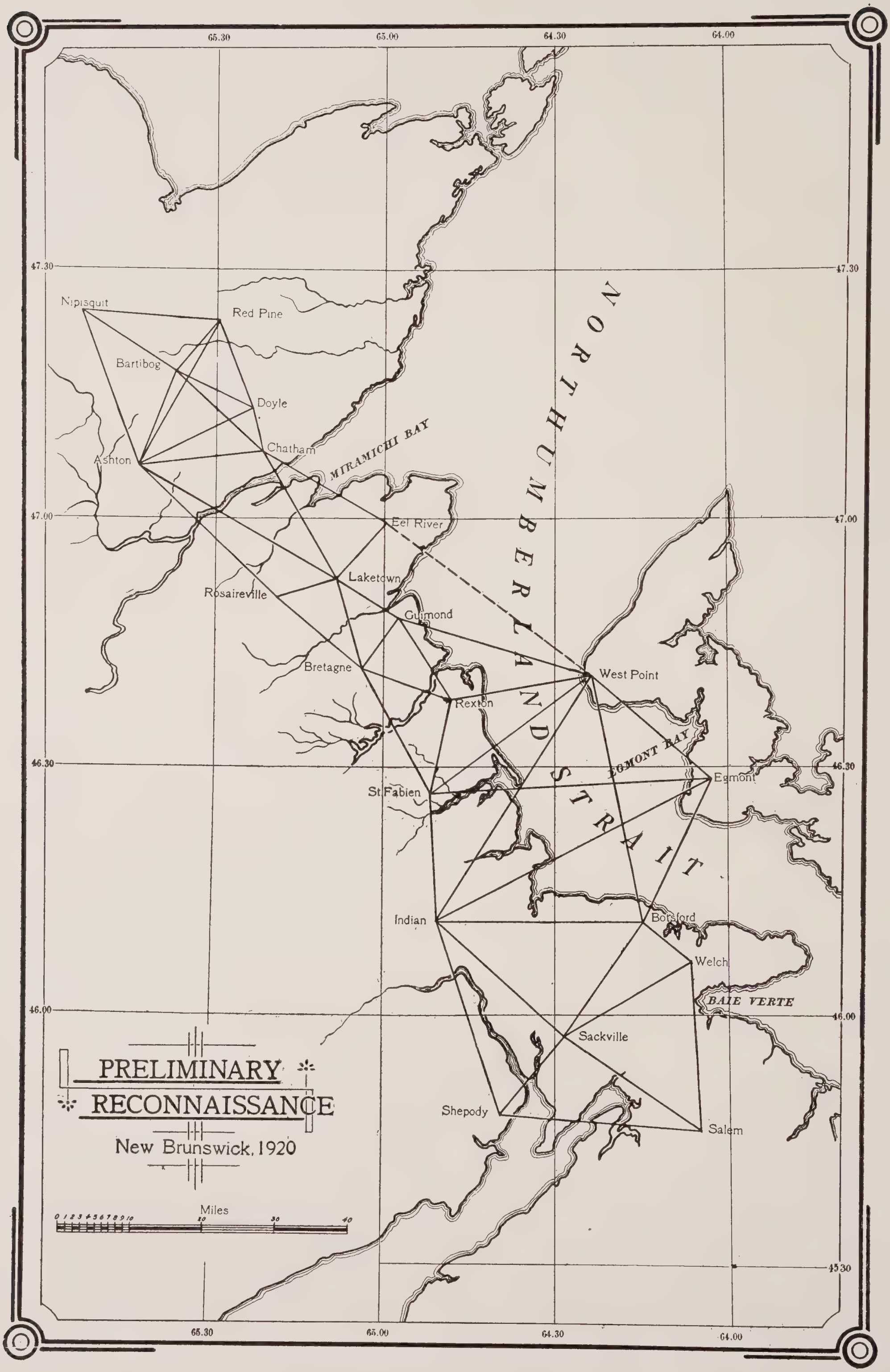
Two parties were engaged on angular measurements, one working on the south shore and the other on the north. Difficulties and delays owing to horizontal refraction, long lines, and haziness of the air rendered the progress slow. Horizontal refraction is the horizontal displacement or bending of rays of light due to pecular air conditions. During the season of 1920 the prevalence of these conditions permitted only about one-half to one-third of the clear weather to be utilized for work. Longer lines require clearer air conditions than shorter lines; furthermore the clarity of the air on the lower St. Lawrence district is inferior to that in western Canada.

Transportation of parties and their supplies was accomplished by the C.G.S. "Gulnare," which was loaned by the Department of the Naval Service. The "Gulnare" is 137 feet long, a ship of this size being necessary on such a stretch of water as the gulf, where harbours are scarce.

Reports of the engineers in charge of operations in Quebec commence at pages 39 and 40.

New Brunswick.—Reconnaissance for triangulation along the east coast of New Brunswick, constituted the activities of the Survey in that province. One of the main purposes of this triangulation is the determination of the geographic position of control points for hydrographic charting of the east coast of New Brunswick and the western end of Prince Edward Island.

This net commences at the Westmorland base net at the head of the bay of Fundy near Amherst, N.S., follows up Northumberland strait, thence up the east coast of New Brunswick to Chaleur bay near Bathurst, N.B. From this point it branches, one part turning east to meet the St. Lawrence river triangulation near Gaspé and Percé mountain, the other branch running west up Chaleur bay towards Campbellton and the Matapedia valley. The reconnaissance of the northern end was not completed in 1920.


PRELIMINARY
RECONNAISSANCE
New Brunswick, 1920
Miles
NORTHUMBERLAND STRAIT
MIRAMICHI BAY
EGMONT BAY
BAIE VERTE
Nipisquit
Red Pine
Bartibog
Doyle
Chatham
Ashton
Eel River
Laketown
Rosaireville
Guimond
Bretagne
West Point
Rexton
Egmont
St Fabien
Indian
Botsford
Welch
Sackville
Shepody
Salem
65.30
65.00
64.30
64.00
47.30
47.00
46.30
46.00
45.30

In general the country is very flat with a covering of timber necessitating the use of short lines and high towers. It is in this type of country that the reconnaissance tower described on pages 15 and 43, is most essential.

The report of the engineer in charge of this piece of reconnaissance commences on page 42.

Nova Scotia.—One reconnaissance party, one tower building party and two angular measurement parties were engaged in triangulation work in eastern Nova Scotia and Prince Edward Island. This work was a continuation of the operations of the past three seasons which had for their particular purpose the extension of the primary triangulation to the Halifax and Sydney vicinities, to provide control points for the military mapping of these districts and for the hydrographic charting of the Atlantic coast to the Magdalen islands and, if possible, to Newfoundland, near cape Ray.

The field work was completed as far as Halifax in 1919, while by the end of the season of 1920 the reconnaissance had almost reached Sydney and the angular measurement had been completed to such a point that only three main stations of this net are still to be occupied on the Nova Scotia mainland. The operations on this net during the 1921 season will be almost all on Cape Breton island.

Detailed reports by the engineers in charge of various parts of the work in Nova Scotia begin on pages 44, 45 and 47.

PRECISE LEVELLING

In the fiscal year 1920-21, to the extent of 1,108 miles precise levelling was accomplished, making the total amount to date 14,031 miles—including the 491 miles levelled in the Yukon in connection with the International Boundary Survey in the years 1908-09-10. Three hundred and eighty-one new bench-marks were established, bringing the total number at the present time to 4,160 (Yukon levelling included).

Following out the previous custom a publication was prepared giving provisional results for about 800 miles of levelling and giving the elevations of 212 permanent bench-marks.

The report of the Supervisor of Levelling giving details of the work accomplished begins on page 48.

STANDARDS

During the past year the usual work in connection with the standardization of the invar base line tapes has been carried out. It had been planned to measure a primary base line on Anticosti island, but on account of the pressure of work on the other parts of the Survey, the measurement of this line was put off for a year. The reconnaissance of the base line and base net has been completed, and during the summer of 1921 the measuring will be done.

The policy of intercomparing the three metre bars of the Survey is being strictly adhered to. By so doing any change in length of any of the bars will be quickly detected, and the strength of our tape line determinations will be much increased.

The precise level rods of the Survey have been standardized from the metre bars. It is the intention to conduct an exhaustive study of the behaviour of wooden rods throughout the year, especially during the working season.

GEODETIC ASTRONOMY

Cap Chat, one of the stations of the primary triangulation on the lower St. Lawrence river, was occupied as a Laplace station. The longitude and latitude of this station and the azimuth of the primary line from Cap Chat to Mechin geodetic points were determined. All along the St. Lawrence the deviation of the plumb line is very large. At Cap Chat this deviation exceeds eighteen seconds of arc. As was to be expected, the plumb line is deflected in opposite directions on the north and south sides of the St. Lawrence river.

At least two other Laplace determinations are required in Eastern Canada. One of these will be made at a station of the base net on the Anticosti island and the second at one of the triangulation stations near Sydney, N.S.

ARCTIC DISCOVERIES

A considerable amount of time has been spent in the reduction and mapping of the work done by Mr. V. Stefansson in his "Arctic Discoveries" from 1913 to 1918. This important work is nearing completion and will add to the map of Canada, territory to the extent of several thousand square miles. Nearly three hundred observations for latitude, longitude and magnetic variation, together with numerous traverses have been used in the production of this map of what Mr. Stefansson claims will some day be an important part of Canada.

EXPERIMENTAL AERIAL SURVEY OF OTTAWA

The application of aerial photography to surveying has received attention, and a large number of photographs of the city of Ottawa taken recently has resulted in a rectified mosaic of the industrial section along the Ottawa river. Experiments were carried out in an extensive way to determine the tilt of the negatives, the rectification required by these negatives, and the use which could be made of photographs taken, with ample overlap in obtaining relief for mapping purposes. Triangulation control was established by means of an expansion through a secondary scheme of triangulation based upon the primary lines Ottawa–King Mountain and King Mountain–Aylmer, and sixty-two fixed points were established. A detailed report of the geodetic engineer in charge of these experiments will be found on page 29. Thus a field of work which from a technical point of view is large and growing rapidly has been opened up in Canada for the first time.

MAPPING

The hill contours of the north half of the surveyed area of the Gatineau River watershed which were not secured in 1913 have been considered available by means of stereophotogrammetry. To secure these contours two small parties were sent out by this survey and placed under the direction of Professor Anderson, of Toronto University. It was desired at the same time to test out the practicability of a new method of surveying contours by this means. Instruments for this work were lent to the Geodetic Survey by the University.

Application was received for a topographical survey of the city of London and, acting upon this, an agreement was signed whereby the Geodetic Survey of Canada supplied the engineers and instruments and the city of London supplied material, labourers, chainmen, etc., and paid for the reproduction of the map. The triangulation net and the precise level net have been completed.

BENCH-MARKS

In the foregoing synopsis mention having been made several times of "bench-marks," it will doubtless be in order to say something as to the character of those used by the Geodetic Survey and the general procedure in regard to their establishment.

A "bench-mark" may be defined as a fixed point, of a permanent nature, whose elevation has been determined and whose position has been so described that it may be identified in the future. It is to be observed that it must be a *fixed* point; no movement should take place after the selection of the bench-mark, as otherwise its utility is to a large extent destroyed, and the more accurately the elevation is determined the more essential it is that the bench-mark should not afterwards be raised or lowered either by natural or artificial agencies.

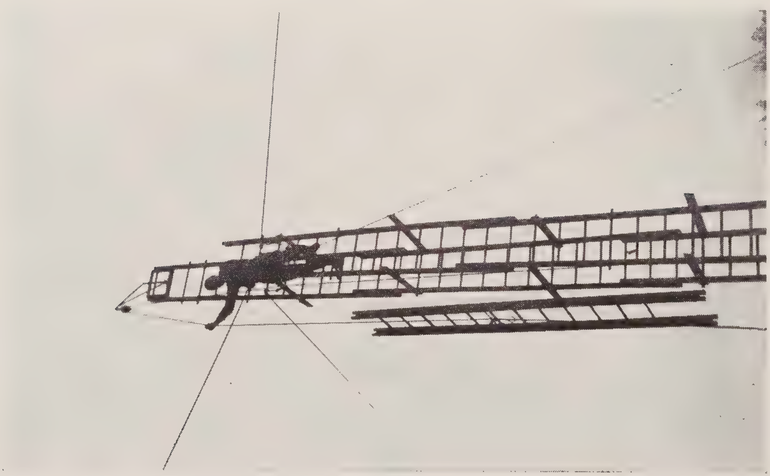
Permanence is another prime requisite of a bench-mark established by a geodetic survey. It is obvious that if all or nearly all the bench-marks in a district were to be destroyed, the elevations determined—no matter how accurately—would not be recoverable, except in so far as the water surfaces of lakes and rivers and the elevations of railway tracks opposite station buildings, etc., might serve the purpose. Such planes of reference are, however, subject to fluctuations and obviously cannot be relied upon to furnish a record for levelling of precision.

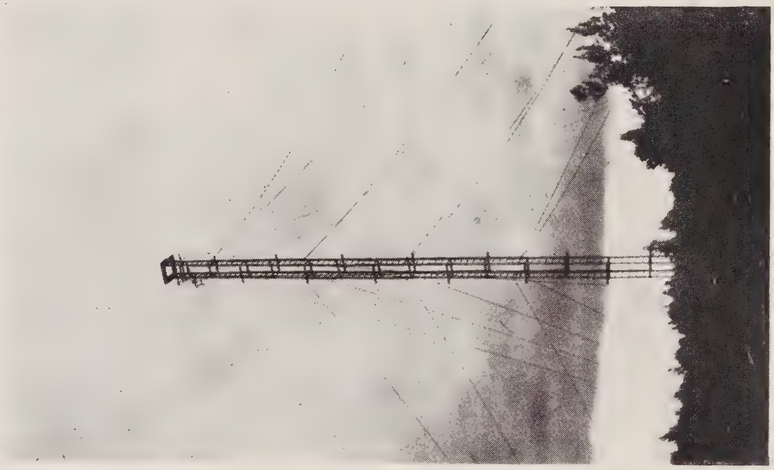
Permanent bench-marks in engineering practice exhibit a wide range in their selection. Copper and brass bolts, bronze discs and bronze plates provided with a small shelf to support the levelling rod have been extensively used, the metal fixture being in most cases attached to a building or other structure or to a natural rock surface. To save time and expense the bolt or disc is often omitted and the exact point is indicated by an arrow or outlined square chiselled in the stonework or concrete. Indeed quite frequently even this is omitted and the point used is not marked in any way, the bench-mark merely being identified by the description as being "at extreme west end of stone door sill" or "on top of water table at northeast corner of post office," etc.

In the precise levelling operations of the Geodetic Survey of Canada it was realized at the outset that it would be of decided advantage to adopt some one type of bench-mark as standard, one that would be permanent, would be inconspicuous and cause no defacement to buildings but at the same time could be readily located and identified, and finally that would furnish an exact plane of reference for precise levels. A copper bolt three-quarters of an inch in diameter and four inches in length was selected as most nearly fulfilling the above conditions. This is set horizontally in solid rock, masonry or concrete, a hole being drilled of the required depth and the same diameter as the bolt or a shade larger; the bolt is hammered till it completely fills the hole, the end being flush with the surface of the containing structure or projecting slightly. If any tendency to looseness is noticeable a bolt slit at the inner end and fox-wedged is used. When properly put in it is impossible for a bolt to be removed without destroying the surrounding rock or masonry. After the exposed end of the bolt has been planed to a smooth surface by means of a file it is stamped with a steel die containing the letters G.S.C., B.M. (Geodetic Survey of Canada, Bench-Mark). Then a horizontal chisel line is cut, upon which the elevation is taken and finally the designating number of the bench-mark is stamped.

The question is sometimes asked, "Why is not the elevation also marked?" Elevations are not marked because the elevation of a bench-mark in a precise level net may not be finally decided upon for a long time; the closing of circuits and introduction of cross lines will call for adjustments which will make changes of greater or less magnitude in the elevations.

At the inception of the work the bench-mark locations were of three general types: (*a*) the exterior walls of buildings, usually public buildings such as post offices, city halls, county court houses, churches and schools; (*b*) bridges and culverts, usually lying along lines of railway; (*c*) outcrops of natural rock, or in some cases boulders, when sufficiently large and deeply bedded. It was soon found that a fourth type—a made-to-order bench-mark—would be necessary if long stretches of line with bench-marks of very questionable permanence or with no bench-marks at all were to be avoided. Consequently, a type of concrete monument was developed which could be built whenever nothing suitable for a bench-mark was available or where it was considered necessary to give added permanence to the levels in any particular locality. These monuments, or "bench-mark piers," extend to a depth of six feet below the ground surface, the excavation for the same being made with the aid of a crowbar and spoon shovel; the upper portion—extending from six inches to one foot above ground—is shaped in the form of a frustum of a pyramid, the top being nine or ten inches square. The customary copper bolt was for the first few years placed horizontally in a side of the pier, but this position not being found altogether satisfactory, the later piers have had the bolt placed vertically in the top.





Dismountable Ladder

(*a*) In course of erection.

(*b*) Complete, 78 feet high.

Except in the case of the bench-mark piers the vertical position of the bolt has been used only in very rare instances; a bolt set vertically in a horizontal surface is liable to be concealed by snow and ice in the winter and by dirt, moss, etc., at any time; moreover, if it projects at all above the surrounding surface its elevation might be changed by a blow. However, it sometimes happens, as in the case of a flat mass of rock almost level with the ground, that there is no choice in the matter and a good opportunity for a bench-mark would be lost were the vertical position strictly ruled out of court.

The choice of suitable sites for bench-marks is a matter calling for the exercise of considerable judgment on the part of the engineer making the selection. As the lines of precise levels in nearly all instances follow railway tracks, the bench-marks are of necessity pretty well confined to the vicinity of the railway except in cases where spur lines are run to establish bench-marks or for other reasons.

The concrete monuments are built on the railway right of way, near one of the fence lines, where they will not be subject to the danger of disturbance from future alterations in the railway grade, and they are whenever practicable located near some feature such as a stream or road crossing. By doing this their positions may be readily identified at any future time.

It is aimed to have the bench-marks on any particular line of levels belong in part to each of the four classes enumerated above—on the principal of not having all one's eggs in one basket. This, however, is not always practicable; in the prairies of the West, for instance, the great majority of the bench-marks will of necessity be in concrete monuments, while in a bush and rock country such as northern Ontario practically all will be in bridge masonry and natural rock surfaces. It is in the older settled portions of Eastern Canada that one finds the greatest choice in bench-mark locations. It may be added that on the western prairies it is the experience of the Survey that but little reliance can be placed in the stability of bench-marks in the foundations of lightly constructed buildings frequently encountered, and it is the practice to depend less and less upon these and more and more upon concrete bench-mark piers.

As noted on a previous page, there are now over four thousand of the standard bench-marks of the Geodetic Survey of Canada: these will be found in all parts of the country between Halfax and Vancouver; 534 of these bench-marks are in the specially constructed concrete piers.

Great care is used that the published descriptions of all bench-marks shall be clear, accurate and concise, as it is felt that the bench-mark descriptions will often be used, perhaps unconsciously, as the criterion for judging the quality of the Survey's work. With this end in view it has been the practice to have all or practically all the bench-marks inspected at some time after their establishment; the descriptions are checked and where necessary revised and put into standard form.

NEW TYPE OF RECONNAISSANCE TOWER

In certain types of country, such as in flat, partly timbered areas, or in city triangulation, the reconnaissance engineer frequently encounters difficulty in determining the height of tower which is required to make certain stations of a triangulation system intervisible; also even from the top of the highest available trees he may not be able to get an adequate idea of the country ahead. In such cases he draws on his experience to determine the height of tower which shall be built with the result that he sometimes recommends too high or too low a tower with the result either of wasted effort or further work when the deficiency is discovered. In city triangulation the lines of sight must pass off the line of any very high building; otherwise, extremely high towers would be required.

In such types of country a reconnaissance tower such as that illustrated on page 11 of the annual report of the Superintendent for 1919 has proved very useful and economical—in certain places it has been found almost indispensable. This type

of tower weighed about 1,600 pounds and, to raise it, required the work of two or three men for five or six hours.

During the season of 1920, two new reconnaissance towers were required, one for the flat, wooded country along the east coast of New Brunswick and the other in Alberta, and it was decided to adopt a different type of tower, one which would be lighter and more quickly erected and dismounted. The type adopted was the Dismountable Observation Ladder of the Geographic Service of the French Army, Two towers were constructed in 1920, each permitting the engineer to ascend to a height of 78 feet above the ground.

The ladder tower is composed of inter-changeable sections joined together end to end, which form two vertical ladders about 2 feet apart, resting on sleepers on the ground and connected to one another by pairs of cross braces at intervals of 5 feet. Four sets of guys placed at 25, 40, 55 and 70 feet from the ground, hold the ladder steady. A table may be placed on the top of the ladder, the engineer's head and shoulders rising through a hole in its centre. This table may hold instruments, maps, etc.

The translation of the Directions for this Dismountable Observation Ladder will be published by permission in the near future in the form of a bulletin. These directions cannot be exactly followed in the practice of reconnaissance surveys by the Geodetic Survey of Canada, since the party consists of only two men.

The advantages and disandvantages of this tower over the type previously used are as follows:—

1. It is not so steady as the older type of tower.
2. It is slightly harder to put up in a heavy wind, since the elements are quite light and more affected by wind.
3. Even though not quite so steady it is perfectly safe.
4. It is quite light, weighing about 1,000 pounds and is conveniently carried in a motor-truck.
5. It is very quickly raised and dismounted, two experienced men being able to raise it in two hours and dismount it in one hour. Thus, except for being slightly less steady, it has every advantage over the older type of tower.

PUBLICATIONS

During the fiscal year two publications have been issued, while two are in press.

Publication No. 5 contains field instructions for angular measurement on primary triangulation. Though specially written for the above purpose, much of its contents is applicable to other classes of work, chapters on direction measurement procedure, use and care of instruments, adjustments of micrometer theodolites, field reductions, etc., containing information which is useful to many engineers.

Publication No. 6 contains results of certain precise levelling operations in Manitoba and Saskatchewan.

Publication No. 7 on Geodetic Position Evaluation is a part of a larger publication on Geodetic theory and problems and is now published to fill the immediate requirements of the survey and others who are doing related work.

Publication No. 8, which is in press at the end of the fiscal year, is entitled "Field Instructions for Precise Levelling," and is the result of some fourteen years of experience in this branch of the Survey's activities.

Following is a list of publications issued by the Geodetic Survey, or in press, to date:—

Publication No. 1—Precise Levelling—Certain Lines in Quebec, Ontario and British Columbia.
Publication No. 2—Adjustment of Geodetic Triangulation in the Provinces of Ontario and Quebec.

Publication No. 3—Determination of the Lengths of Invar Base Line Tapes from Standard Nickel Bar No. 10239.

Publication No. 4—Precise Levelling—Certain Lines in Ontario and Quebec.
Publication No. 5—Field Instructions to Geodetic Engineers in charge of Direction Measurement on Primary Triangulation.
Appendix No. 1 of Publication No. 5—Instructions to Lightkeepers on Primary Triangulation.
Publication No. 6—Precise Levelling—Certain Lines in Manitoba and Saskatchewan.
Publication No. 7—Geodetic Position Evaluation.
Publication No. 8—Field Instructions for Precise Levelling. (In press).
Annual Report of the Superintendent of the Geodetic Survey of Canada for the Fiscal year ending March 31, 1918.
Annual Report of the Superintendent of the Geodetic Survey of Canada for the Fiscal year ending March 31, 1919.
Annual Report of the Superintendent of the Geodetic Survey of Canada for the Fiscal year ending March 31, 1920.

The following are summaries of detailed reports of engineers in charge of the various sections of the work.

Respectfully submitted,

NOEL OGILVIE,
Superintendent.

ADJUSTING OFFICE

The work of the adjusting office, under the direction of Mr. W. M. Tobey, Senior Geodetic Engineer, is summarized under the following heads:—

1. Field Inspection.
2. Refinement and Correction of Field Data.
3. Progress in the Adjustments (including level adjustment).
4. Determination of precisions of probable accuracy of sides and other external parts of the triangulation or of a level net as advisory for new field work.
5. Determination of finished data; its necessity for engineers, surveyors and the general public.

FIELD INSPECTION

During the summer an inspection of the general lay-out of the triangulation scheme of the province of British Columbia was made. This important piece of triangulation has been pushed along the strait of Georgia and is now as far north as Queen Charlotte sound. The prevalence of fog undoubtedly makes the observing work most difficult and is even liable to make the accuracy of the triangulation suffer a deterioration unless close scrutiny of the many variable factors is maintained. While the Laplace points of Lazo and Klucksiwi and the base at Fort Rupert have undoubtedly done much to control the accuracy of the triangulation, yet it may be possible that due to peculiar conditions certain outstanding errors may have to be controlled.

Later in the year the precise level work near Regina was investigated and Canada is fortunate in having such a complete system of reliable bench-mark elevations along her railways which will serve more and more with time, as an engineering basis for all level work done by private corporations or by government departments.

REFINEMENT AND CORRECTION OF FIELD DATA

The usual methods of testing the field data were employed. Only by a close scrutiny of the angle and side equations can an *accumulation* of field errors be prevented. To this end the angle and side equations were tested to see if they were of the required accuracy, the side equation test for primary work being that the average correction given by the adjustment should not be greater than $0 \cdot'' 4$. Secondary work was examined by similar methods.

The field operations for the year which called for special attention by the adjusting officer were confined chiefly to the extension of the British Columbia net past the Fort Rupert base to Calvert and Seymour; the extension of the river St. Lawrence triangulation to Trinity (see chart p. 19); and the extetnsion of the Nova Scotia and Prince Edward Island triangulation so that the observing included the stations Red Point, P.E.I., and McDonald (see chart p. 26).

During the year many descriptions of triangulation stations have been received and revised. These are essential to the public in recovering these stations. It is part of the duty of the cataloguer to see that such descriptions are so filed and indexed with other matter as to be readily available. An indexing of all matter under *name of station* has given excellent results.

Great emphasis must be placed on the proper relation of the reconnaissance work to the previous work which forms its basis. In every case the inherent errors or weakness of the previous must enter the new work. Hence great care must be exercised in building upon those parts of previous systems that have a strong basis.

The reconnaissance that was initiated this year included a section of triangulation in the vicinity of the 111th meridian based on the United States coast and Geodetic Survey points Sweetgrass and Simpson's (see p. 33); the reconnaissance of the lower St. Lawrence to Percé and including the island of Anticosti (See p. 19); the reconnaissance of the province of New Brunswick from Sackville to Red Pine (see p. 10); and lastly the reconnaissance of Nova Scotia and Cape Breton, carrying the triangulation scheme to Kelly and Big Rock (see p. 26). The latter scheme will it is hoped, enable the Geodetic Survey of Canada to soon fulfil the requests of the Militia Department for the positions of the points Ciboux island, Fourchu bay, Sydney and Boularderie island, points which are used as governing points for topographic work.

PROGRESS OF THE ADJUSTMENTS

The adjustment of the precise level net of Western Canada has developed so that the precisions of elevations of different points have been ascertained. These precisions show that the Canadian net should depend on more initial points than that of Stephen, Minn., and Vancouver, B.C.

To this end, after consultation with Mr. William Bowie, Chief of the Division of Geodesy, and Mr. H. G. Avers, of the United States Coast and Geodetic Survey, it was decided by the superintendent to run lines of levels southwards to connect with the United States level net, and at the same time to make use of the United States bench-marks at North Portal, Coutts and Port Hill.

By this arrangement many of the long easterly and westerly lines of the Canadian net will be strengthened by new data and this will undoubtedly have a wholesome effect on the precisions of the elevations.

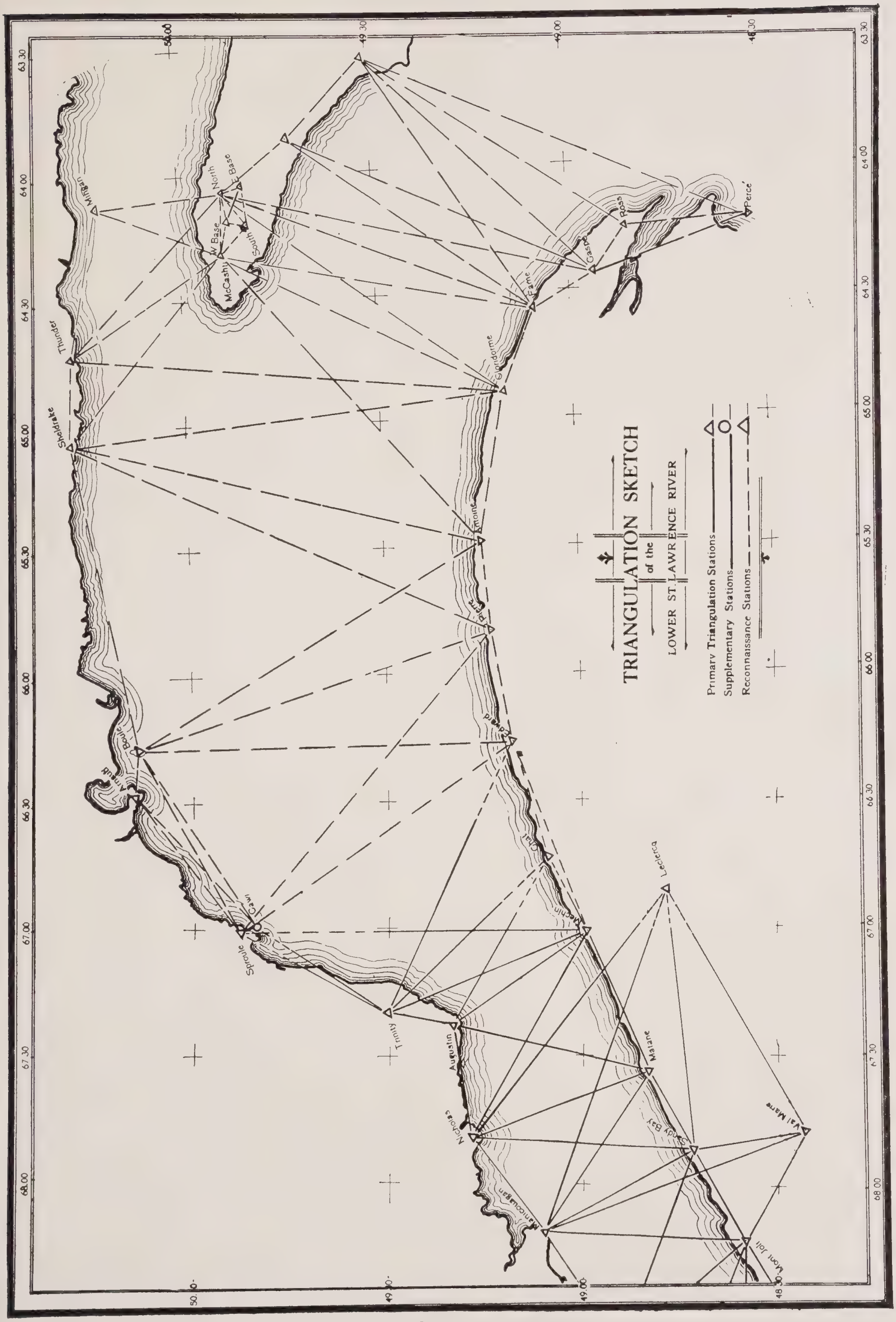
The incorporation of the level results of the Topographical Surveys Branch will also have a most wholesome effect, for the larger the net the more the tendency to localize peculiar errors and the greater the reliance that can be placed on determined precisions.

A preliminary adjustment of the level net of Eastern Canada is also in progress (see inside back cover). This net is based on one United States point, namely, Rouse Point, and on the tidal stations at Halifax and Father Point.

The Western Ontario triangulation net comprising two Laplace stations and two bases is nearing completion. It has been used this year as a basis for the city of London triangulation (see p. 27).

DETERMINATION OF THE PRECISIONS OR PROBABLE ACCURACY OF SIDES AND OTHER EXTERNAL PARTS OF THE TRIANGULATION OR OF A LEVEL NET AS ADVISORY FOR NEW FIELD WORK

This is a subject that always needs the care and attention of the office, since errors of the old triangulation must affect the accuracy of work in progress.


TRIANGULATION SKETCH
of the
LOWER ST. LAWRENCE RIVER
Primary Triangulation Stations
Supplementary Stations
Reconnaissance Stations
Mingan
Thunder
Sheldrake
North
E Base
W Base
South
Ross
Percé
Gaspé
Fame
Boule
Sproule
Trinity
Augustin
Nicholas
Manicouagan
Leclercq
Matane
Sandy Bay
Val Marie
Mont Joli

Hence it may be stated in general terms that as a guide for the prosecution of new triangulations, beginning on certain sides of the old triangulation, the probable accuracy of the lengths of such sides should be known, as well as that of other parts of the old triangulation. Only by a knowledge of the probable accuracy of these sides can a decision be made as to the approximate position of base lines in any new triangulation based on the old.

In the adjustment of a precise level net we require to know the accuracy of the elevations of points and of differences of elevations along certain routes. Remembering that the elevations of points have different values depending on the route taken by the different precise level lines of the Geodetic Survey, the Topographical Surveys and the Public Works Department, it becomes desirable that the most probable accuracy of each line of levels should be known, together with the most probable value of the accuracy of the elevation of the points in question. Only an adjustment based on the mathematical basis of probability and free from preconceived ideas of the accuracy of various lines of levels can give results which will not show arbitrary and conventional handling.

DETERMINATION OF FINAL DATA AS SUITABLE FOR ENGINEERS, SURVEYORS AND THE GENERAL PUBLIC

The general determination of finished data free from clashes and incongruities, depends upon a study of the theory of errors, so as to bring about an adjustment of all the data, to give the most reliable values.

It is therefore necessary to do everything possible to increase the accuracy of such values. As mentioned above when discussing adjustments this is done by the inclusion of as much of the field data in one net as is possible.

Preliminary results are, however, generally determined as the field data is secured, in order to meet the demands of those engineers for whom preliminary results are sufficiently accurate.

In the case of the precise level net in Western Canada, where one preliminary adjustment has already been made and valuable knowledge concerning elevations and accuracies of points obtained, other preliminary adjustments will be made as new material is available until it can be said that the incorporation of new material has little or no effect upon the old and that the most reliable results have been determined.

CITY MAPPING DIVISION

Douglas H. Nelles, Supervisor of Topography, makes the following report.

Thirtyone Mile Lake Watershed.—Two parties under Professor G. R. Anderson of the University of Toronto were engaged during the season in finishing the mapping of the north half of this area, that is in locating the contours of the hills; the roads, streams, lakes and farms had been surveyed in 1913. After being one month in the field Professor Anderson was recalled to the University, and B. J. Woodruff, engineer of the Geodetic Survey staff, took charge of the parties and assisted by Assistant Professor K. B. Jackson, of the University of Toronto, did the stereophotogrammetric part of the work; J. Q. Coughlan, engineer of the Geodetic Survey staff, did the triangulation reconnaissance in locating and clearing of the stations ahead of the observing party.

Stereophotogrammetric surveying is a new method of surveying by means of photographs. Until last year no practical application of this method on any extended scale had been made in America. The only instrumental outfit in Canada is owned by the University of Toronto, who very kindly lent it to the Geodetic Survey to test out the method in a practical way over a large area, namely 100 square miles.

Following is the summary report of the engineer in charge. The plotting of the season's work is only partially completed. In the next report a detailed account of the field and office methods and the theory of the field and office instruments will be given.

Report of B. J. Woodruff, Geodetic Engineer in Charge Stereophotogrammetric Survey

On July 5 Professor W. R. Anderson and party left Ottawa for Point Comfort, P.Q., one additional man being hired as boatman at Point Comfort. The first work carried out was the erection of signals on main triangulation stations, and on July 10 camera work was begun. During July six stations were occupied and six main triangulation signals erected as well as one tower built. On July 30, camp was moved about ten miles northward to McKenzie's farm and on August 3, Professor Anderson left for Ottawa.

During August, September and up to October 12, twenty-two stations were occupied and the locating and preparing of new stations completed. On October 13, camp was moved to the outlet of Thirtyone mile lake and during the remainder of October and up to November 26, sixteen stations were occupied. On November 26, camp was broken up and the greater part of the equipment sent out to the railway with the cook, while Mr. Coughlan, the writer and one axeman remained to finish a short traverse of the road near Bois Franc lake, which was completed on December 1.

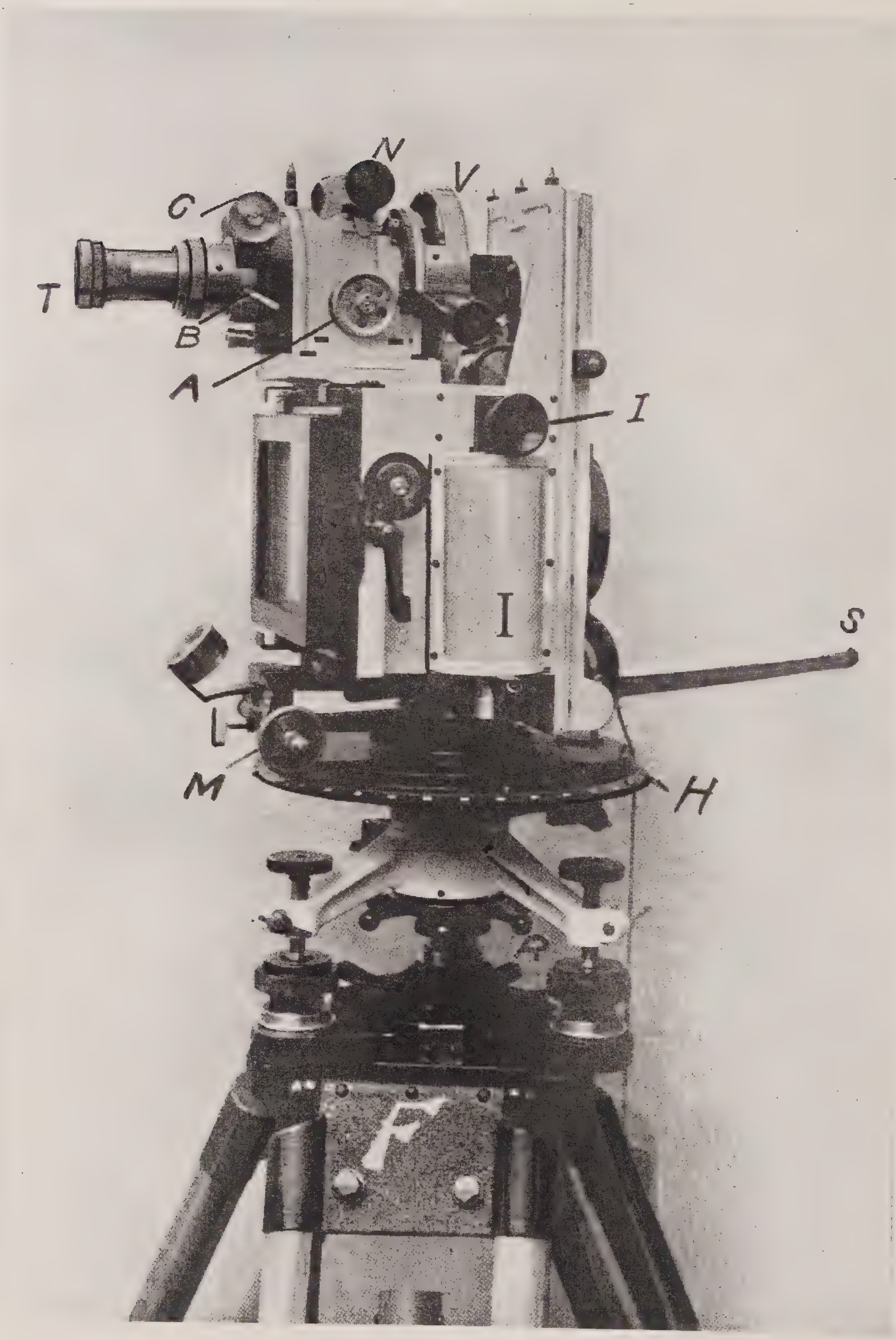
During the season forty-four stations were occupied, and 280 plates exposed. The average number of bases per station was 3.18 making the average number of plates per station 6.36.

PHOTOTOPOGRAPHY

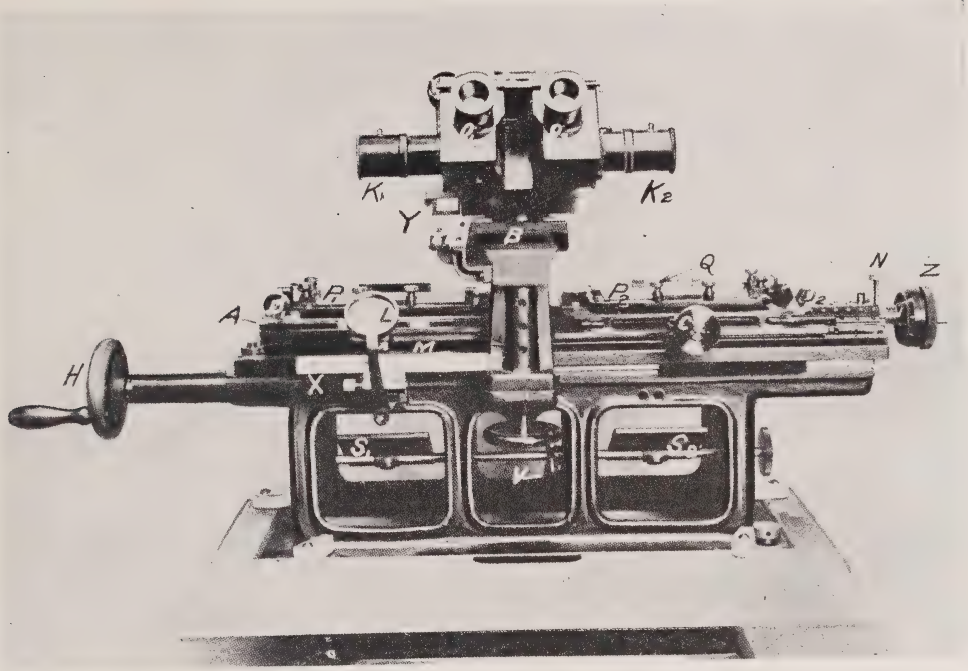
In the old method of phototopography used upon the survey of the international boundary line between Canada and Alaska, topographic control points were plotted from photographs taken at widely separated stations, from one to ten miles apart. In order to get accurate results these points must subtend a fairly large angle and this condition in a district like the northern half of Thirtyone Mile Lake country where the hills are thickly wooded, makes it very difficult to recognize the same control point from two photographs. In the stereophotogrammetric method two photographs are taken, one from each end of a short base by a phototheodolite instrument as illustrated on page 22, in such a manner that both are in the same vertical plane. To get accurate results the length of the base should be around 10 per cent of the distance to the farthest points to be plotted. The distance between photographs being so short it is easy to recognize in each photograph as many points as desired to control the topography. The method of plotting this work is quite different from the intersection method. The negatives themselves are put in an instrument called a *stereocomparator* illustrated on page 23, and the distance and elevation co-ordinates are measured with extreme accuracy. These co-ordinates are then scaled off on the specially prepared plotting board illustrated on page 23 and the position and elevation determined. When the positions of enough points to control the topography of a certain section have been determined and marked upon the tracing paper by which the plotting board is covered, the tracing paper is removed and the points transferred to the map, after which from an examination of the country from the photographic enlargements and the co-relationship of the points, the contours are drawn.

SURVEY OF THE CITY OF LONDON, ONT.

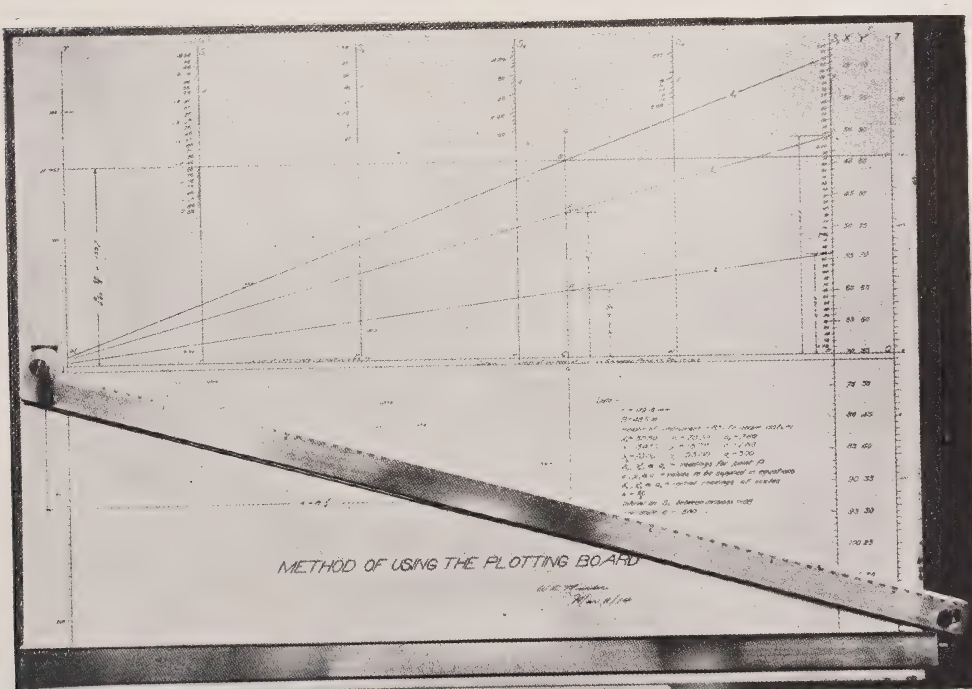
The topographical survey of a city consists of six, more or less, distinct operations: precise level net, secondary level net, triangulation net, traverse net, the measuring in the natural and artificial features to be shown on the map, and the locating of the contours showing the modeling or configuration of the ground surface.



Phototheodolite Instrument: Two photographs in the same vertical plane are taken; one from each end of a short base line



Stereocomparator; from the negatives, distance and elevation co-ordinates are measured with extreme accuracy



Specially prepared plotting board; co-ordinates are scaled to determine position and elevation

The triangulation net is surveyed by engineers from the triangulation division of the Survey, who work in close co-operation with the engineer in charge of the topographical division, especially during the reconnaissance work in locating stations. The main object of the triangulation is to control the traverse net, and stations are placed as nearly as possible a mile apart along the main traverse lines. The London net consists of thirteen stations from which observations were made and eight intersection stations as shown on the progress map of London, inside back cover. Four of these stations form a quadrilateral of the primary triangulation of Canada. The remaining stations were established during the season and are placed so as to form a precise control for all lineal measurements of the survey. The net was adjusted by the co-ordinate method of adjustment. A more detailed account of this operation by the engineer in charge will be found on page 36. The precise level net is surveyed by engineers from the levelling division of the Survey, who also work in close co-operation with the engineer from the topographical division. The object of a precise level net is to establish a large number of permanent bench-marks around and through the city, of a high degree of precision, which while giving elevations themselves for any engineering work in their immediate vicinity, also serve to control lines of secondary levels. The word permanent above is used in a relative sense, as in establishing the permanency of any structure the economic factor of the cost of construction has always to be taken into consideration If a copper bolt had been cemented into the floor of the King room in the Great Pyramid of Ghizeh in Egypt and its elevation established, it would probably be intact to-day, but the probability is that in 25,000 years from now all the present bench-marks in London will have disappeared. The precise level net of London consists of forty-one miles of line, which is composed of a line making a complete circuit of the city. The city is further divided into sections by four east and west cross lines and five north and south cross lines. The cross lines start from and close on the circuit line or themselves. The whole net has been adjusted by least squares and the most probable values assigned to the various bench-marks. The closing error per mile of line was 0·0025 feet, and the average closing error of line between bench-marks is 0·001. Ninety-five permanent bench-marks were built and their elevations established. Fourteen of these called class "A," consisted of a concrete pier six feet six inches long set in the ground with six inches above the surface in the top of which was set a ¾″ copper bolt to hold the elevation. Fifty-one bench-marks, class "B," consisted of a two-inch galvanized iron pipe six feet long, the bottom of which was split and spread so as to prevent vertical movement. The bottom of the bench-mark was placed five feet six inches below the surface and concrete a few inches in depth, was placed in the bottom of the hole to further prevent vertical movement. Thirty bench-marks consisted of a copper bolt set vertically in concrete sidewalks, bridge or culvert abutments and horizontally in foundations of buildings, class "C" and "D". Further information in regard to the precise level net will be found on page 36.

The following is the summary report of the engineer in charge of the survey of London.

Summary Report of F. P. Steers, Geodetic Engineer in Charge of the Topographical Survey of London, Ont.

With instructions to start a topographical survey of the city of London, Ont., the writer left Ottawa, June 23, and spent a month assisting Mr. A. M. Grant, who was doing reconnaissance for the city triangulation. Mr. S. O. Roberts arrived in London July 16 and assisted with the triangulation until the twenty-first when work was started preparing lines for precise traverses.

A system of precise traverses has been laid out for the city. These are divided by name into two classes, but the methods of survey are of about the same accuracy. The main traverse lines start from and close on triangulation stations between which

the stations and controlled lines are adjusted. The secondary traverse lines start from and close on an adjusted station of the main traverse.

The traverse net is so designed that the main lines are about half a mile apart and run along the streets along which the long side of the block lies. The secondary traverse lines run along the streets which present the shortest side of the block. This placing of the lines while it gives the same number of angles to be measured, gives the shortest length of line and so decreases the cost of the measurement. The system leaves one station at one corner of each street intersection, which is marked by a half-inch copper bolt cemented into the sidewalk. This bolt besides constituting a distance co-ordinate, becomes a bench-mark of an accuracy good enough for all ordinary needs of city engineering.

The traverses surveyed during the 1920 season comprise 12·5 miles of line, containing 124 stations or about 10 stations per mile; besides this 33 bolts were placed in position. The position of these lines takes in the most thickly built-up section of the city around Dundas and Richmond streets, as shown in the attached progress map. (See inside back cover).

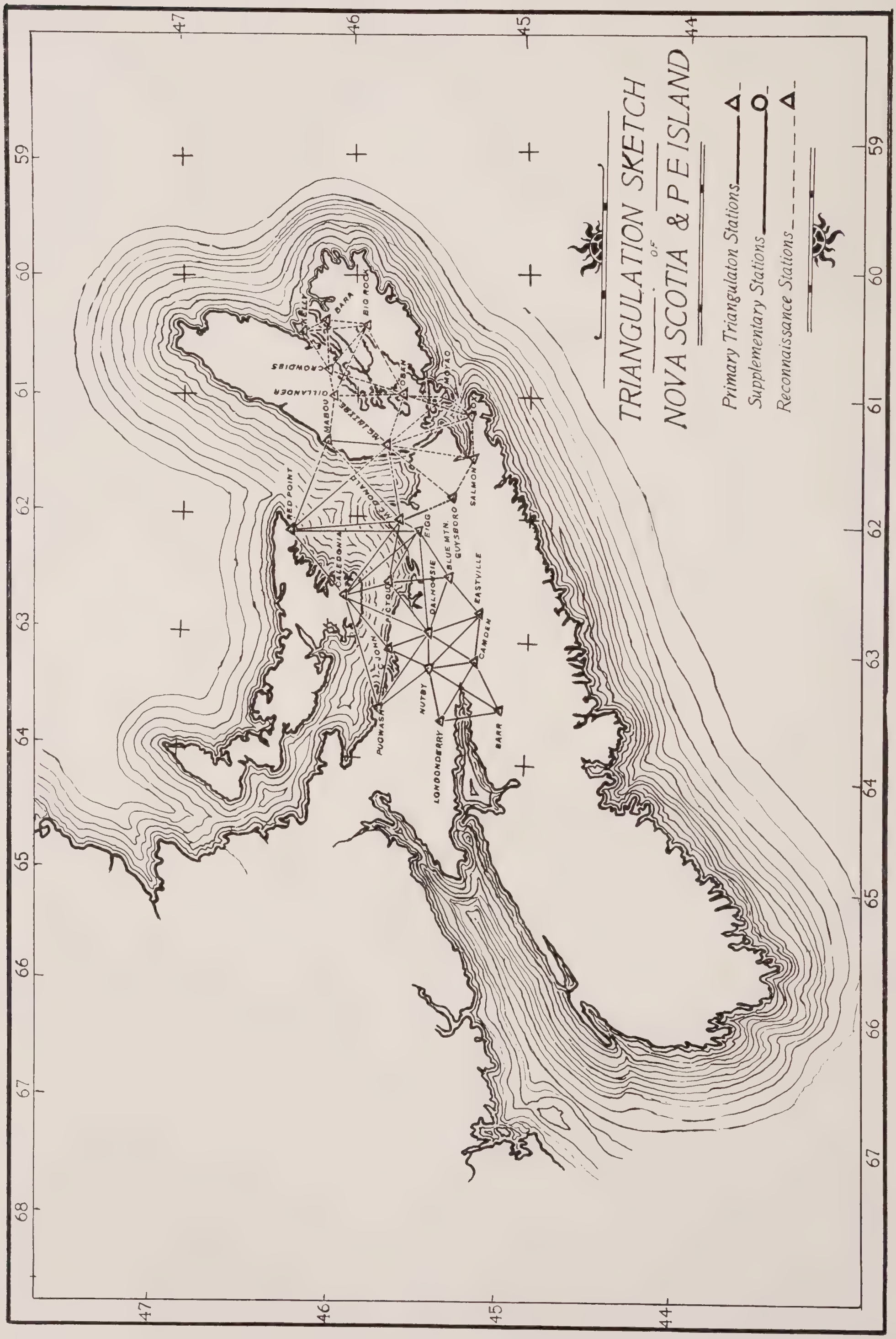
All distances as shown in the Geographical Position List of the triangulation are mean sea-level distances. All the chained measurements taken in London are at an average elevation of 820 feet above mean sea-level, so that a distance of 5,000 feet at mean sea-level on being projected to an elevation of 820 feet would increase to 5000·196 feet. As errors of our traverses will be much smaller than this, the datum of the lineal measurements of London have been placed at 820 feet above mean sea-level.

The mathematical co-ordinates of the survey will be rectangular. Holeproof triangulation station has been chosen as the zero of the co-ordinates and as the city engineer desires to have the edges of the map sheets parallel to the street lines, the datum line for the co-ordinates will be a line passing through Holeproof station parallel to Waterloo street line or nearly so. All the bearings of the survey will be referred to this line. All the distances and bearings of the triangulation have been re-calculated on the above datums and the position of the triangulation stations are being listed by rectangular latitude and departure co-ordinates in the same manner as the traverse stations.

Secondary levels are run over all traverse lines and start from and end on an adjusted bench-mark. They serve four purposes; first, to establish the elevation of all traverse bolts and thus render them permanent bench-marks; second, to establish the elevations of such extra bench-marks as the city engineer desires to have put in; these are generally of the shelf design, class "E;" third, to obtain the elevation of the points along the traverse lines where the grade changes; giving information for chainage correction for grade; fourth, to obtain spot levels to help out in the work of fixing the location of contours. Fourteen miles of secondary levels was run during the season, establishing the elevation of 168 permanent bench-marks, consisting of 145 traverse station bolts and 23 bench-marks, class "E." The average closing per mile of line came to 0.016 foot, which is an average closing of line between bench-marks of 0.0013 foot. The elevation of the secondary bench-marks resulting from the adjustment of the secondary level net, should be of a high degree of accuracy.

Mapping details consist of hydrants, manholes, drainage grates, fences, sidewalks, buildings, etc., being all the natural and artificial features to be shown on the map. The part chosen for the last season's work was the most congested in the city and therefore the most expensive to measure up. In this business district an engineer and two assistants averaged nine acres a day. In a residential district the average would be much higher and in open country like that in the vicinity of the asylum the average would be around thirty acres; this would include the contours as well.

During the winter experiments have been carried on which seem to show that the details of the interior of residential city blocks can be obtained from aerial photo-


TRIANGULATION SKETCH
OF
NOVA SCOTIA & P E ISLAND
Primary Triangulation Stations
Supplementary Stations
Reconnaissance Stations
RED POINT
CALEDONIA
PICTOU
JOHN
PUGWASH
NUTBY
LONDONDERRY
BARR
CAMDEN
EASTVILLE
DALHOUSIE
BLUE MTN.
GUYSBORO
EIGG
SALMON
MABOU
GILLANDER
CROWDIES
BARA
BIG ROCK
OBAN
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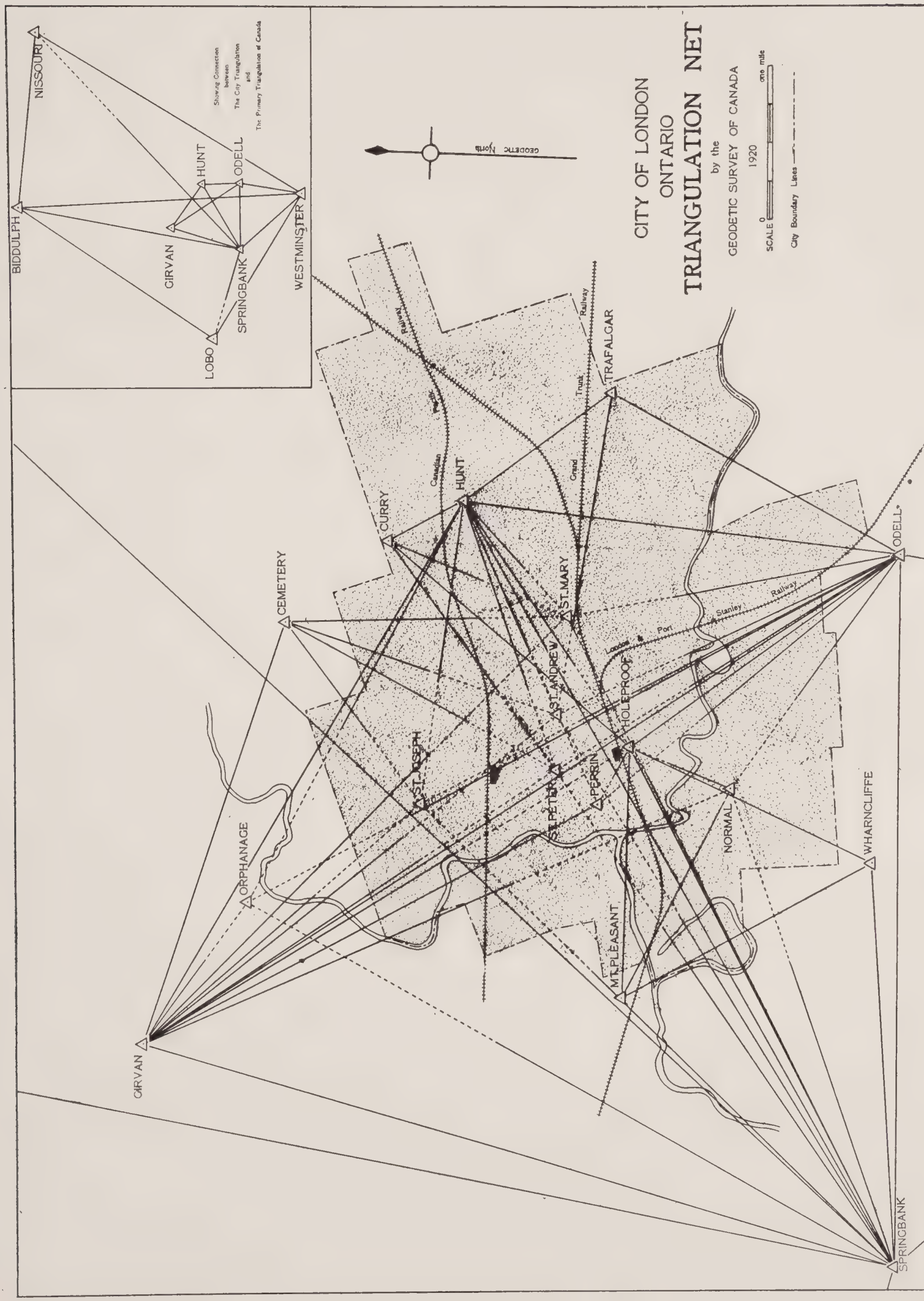
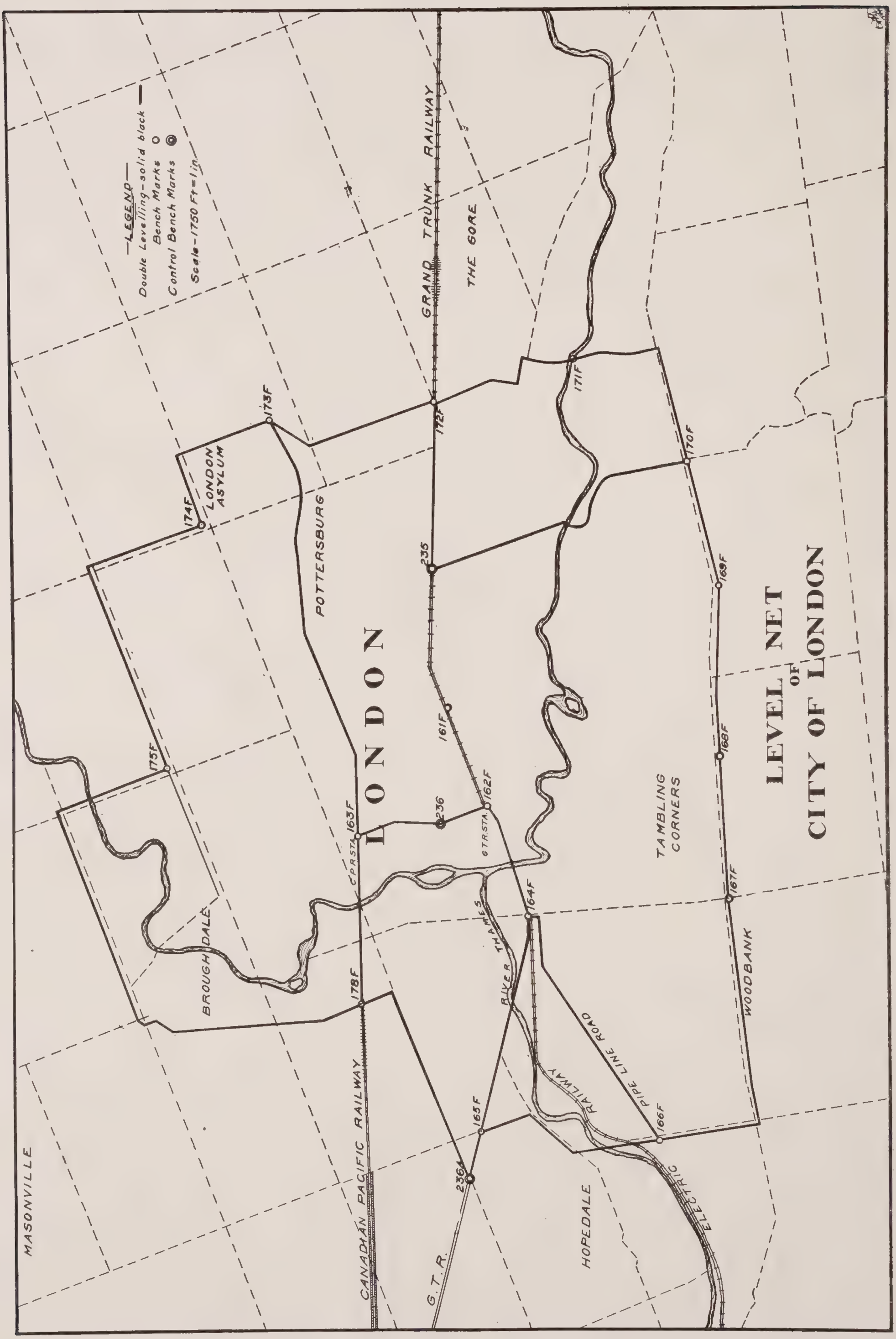

CITY OF LONDON
ONTARIO
TRIANGULATION NET
by the
GEODETIC SURVEY OF CANADA
1920
SCALE
one mile
City Boundary Lines
GEODETIC North
Showing Connection between The City Triangulation and The Primary Triangulation of Canada
NISSOURI
BIDDULPH
HUNT
ODELL
GIRVAN
SPRINGBANK
WESTMINSTER
LOBO
CURRY
CEMETERY
TRAFALGAR
ST. MARY
ST. ANDREW
HOLEPROOF
ST. JOSEPH
ST. PETER
PERRIN
ORPHANAGE
NORMAL
WHARNCLIFFE
MT. PLEASANT
Canadian Pacific Railway
Grand Trunk Railway
London & Port Stanley Railway


—LEGEND—
Double Levelling-solid black
Bench Marks
Control Bench Marks
Scale-1750 Ft=1in.
LEVEL NET OF CITY OF LONDON
LONDON
GRAND TRUNK RAILWAY
THE GORE
POTTERSBURG
LONDON ASYLUM
173F
174F
172F
171F
170F
169F
168F
167F
166F
165F
164F
163F
162F
161F
175F
178F
235
236
236A
C.P.R.STN.
G.T.R.STA.
RIVER THAMES
BROUGHDALE
TAMBLING CORNERS
WOODBANK
PIPE LINE ROAD
RAILWAY
ELECTRIC
HOPEDALE
G.T.R.
CANADIAN PACIFIC RAILWAY
MASONVILLE

graphs with sufficient accuracy to be within the scale of the map. The Air Board has consented to take aerial pictures of London for the Geodetic Survey, as an experiment to see what can be done in this regard. With this information it is also intended to see how accurate a photographic mosaic of the city can be made on the same scale as the map scale. During the season 14 days were spent on detail work and 121.92 acres measured up. Eleven days were spent in contouring 80.14 acres of this section.

EXPERIMENTAL AERIAL SURVEY OF OTTAWA

H. F. J. Lambart, Geodetic Engineer, submits the following report on the Experimental Aerial Survey of Ottawa:—

Object and Aims of the Investigation.—The application of aerial photography to surveying has long been in the minds of engineers and topographers and efforts to try out some experiments were commenced shortly after the armistice of 1918. These efforts finally took shape in the spring of 1920 and during the subsequent summer months the first experiments of this sort in Canada were carried out.

In the absence of anything but war equipment consisting in an L.B. (Mark 1) semi-automatic aero camera manufactured by Williamson's, London, which was rigidly attached to the aeroplane body, some means had to be supplied to determine fundamentally the tilt of the negatives that were to be taken, secondly the performance of the photographic operations in the rectification of these negatives, and lastly the extent to which photographs with a large overlap could be utilized in obtaining relief. To make this information available, many points of the country to be covered, that were easily identified from the air, were fixed in position and elevation as an initial step.

Triangulation Control Survey of Ottawa.—Expansion through a secondary scheme of triangulation from the primary lines Ottawa–King Mountain and King Mountain–Aylmer was carried out and from the points thus established, sixty-two other points were fixed. (See sketch of triangulation net inside the back cover).

Apparatus and Machines Available.—The installation of the camera occupied a considerable amount of time as several arrangements of fitting it to the fuselage were carried through before the final and successful installation was completed in the "Bristol Fighter" No. 433, Rolls-Royce, Falcon III, 220 horse-power engine. The camera installed as already stated was an L.B. (Mark 1) semi-automatic aero instrument for plates 4 inches by 5 inches, focal length 8½ inches in which Ilford Panchromatic and Wrattan Panchromatic plates were used. The installation was made so that the camera was supported on a frame suspended in a cradle of the bell-crank and spring form of construction. The camera was supported on this frame at the centre of gravity and shock absorbers were introduced consisting of sponge rubber to take care as much as possible of the transverse vibration. In addition spring supports were applied to the four corners of the lower mounting which apparently assisted greatly in absorbing shock. This constituted the rigid installation of the camera in the "Bristol Fighter" with which the photographs covering the city of Ottawa and some of the outlying country were taken.

The camera was levelled transversely on the ground with the wings level. To provide for the camera being level in the direction of the line of flight while in flight, the mounting was made to hinge along the front side and could be swung up and clamped in a level position just before commencing photographic operations.

A few photographs were taken at 5.000 feet, but the territory covered by these was covered by photographs taken at a 10,000-foot elevation.

Rectified Photographs.—Rectification of the photographs into a small mosaic was now undertaken.

A complete coincidence of all the points in the rectifying camera could not be made, as the points are all on different levels, but a fair average coincidence of all the points or the most widely separated three was made.

The tilts given to four negatives composing the first trial mosaic in each case are:—

Photographs from left to right:

Inclination lengthwise (banking)	Inclination across
00 degrees	3 degrees
00 "	5 "
5 "	2 "
2 "	4 "

Improvised Rectifying Camera.—Through the assistance of the Natural Resources Intelligence Branch and the kind co-operation of Mr. Sherrin an improvised camera was put together and these rectified photographs obtained. Four movements had to be brought into adjustment before the rectified print was obtained, that is the rocking of the copying board in two directions out of the vertical and the racking backward and forward of the copying board and of the lens along the horizontal base of the apparatus.

The plotted positions to the scale required were pinned to the copying board and the corresponding images in the negative made to coincide with its plotted position. The operation proved a lengthy affair with some of the negatives.

With the 12-inch Acuplat Series 1.F.8. stopped to F.16 the depth of focus was considered—for this experiment at least—sufficient without having the additional two adjustments of tilting the plate.

The operation in a regular rectifying camera is made much simpler by providing as well free movement of negative and copying board in their own planes and by combining the rocking of the copying board and lens in one operation.

The great value of the mosaic in itself is not yet fully appreciated. The amount of information it contains is infinite, and the more it is studied the more it appeals to the engineer who is not altogether concerned in feet and inches.

Errors in Mosaics.—The distortions of a mosiac are chiefly due at present to an inclined plate. When this is corrected by means of control on the ground or by the design of a mounting and stabilizing device which will maintain the optical axis in a vertical position, there still remains the error due to relief, which obviously can never be wholly eliminated from the mosiac.

The amount of the displacement depending upon the angle at which the light from the objects enters the lens and the height of the relief, distortion is absent for points vertically below the camera, but gradually increases as the edges of the negative are reached.

The greater the altitude the more nearly parallel become the rays, and the less the distortion due to relief.

Distortion due to uneven expansion and contraction of the printing paper is of the first order and must be carefully guarded against. The film, although infinitely easier to handle, especially when a large number of exposures are being made, is difficult to keep flat—any unevenesses tending to change the focus and distort the image.

Distortion due to inclined plate.—Over country where no control exists distortion due to inclined surfaces of the negatives is ever present until the problem of the stabilized camera is applied.

The greater the altitude the smaller this distortion becomes. An inclination of five degrees with an eight and a half lens on a stretch of country covered by the corresponding length of the plate (5 inches) would scale too long by 96 feet, or in one mile 86 feet too long.

Experimental and research work necessary.—The knowledge that engineers all over the world are trying to obtain is whether or not a large scale topographical map showing elevations by means of contours can be plotted from aerial photographs and what degree of accuracy can be obtained. This was the information desired by this experiment.

Given sufficient overlap and well rectified photographs a traverse of the flight of the machine can be made; the position of the successive positions of the vertical optical axis being the ends of the courses. This can be done by apparently simple geometrical construction, the initial requirement being that two or more control points whose elevations are known appear in the first photograph. The plotted traverse of a strip of overlapping photographs could be adjusted between control points first, and later the topography worked up from the adjusted photographs.

The problem to work on is not stabilization of the camera mounting—which is being more efficiently investigated than we can do it here—but the production of a mosaic in which the surveyor and engineer is interested only in so far as it is capable of giving him correct measurements and enabling him to place on the map accurately topographical detail.

Equipment.—The plate being less subject to warping and free from expansion is no doubt much more preferable than the film, yet the difficulties of making large series of continuous photographs is seriously against it, and the extra expense involved in having to return to the ground station to get refilled makes the film camera a much more adaptable equipment to work with.

If the question of stabilizing the camera and the rectifying of the photographs are well in hand, it would be well to direct most of the efforts of those carrying out this experiment to the consideration of the development from a geometrical standpoint. By this is meant the working out of a method of geometrically plotting points in position and elevation which are shown in two or more photographs.

Location of photographer in the air at the time of exposure.—It will be necessary to find out with what accuracy the air position of each photograph can be calculated, and the best methods of obtaining the information necessary for this calculation.

Publication.—The publication of mosaic sheets is a large field just in its infancy and will receive the attention it deserves, it is hoped, from the branches of the service carrying out map production.

Their use to the general public can hardly be overestimated as they will be far more easily read and understood than a map and infinitely more interesting. They are invaluable to the town planner and go a long way in solving most of his problems. But fundamentally from the nature of its construction the mosaic will never take the place of the large scale city map for the use of the city engineers where precise measurements are required. The problem of the air photograph is to so determine its position and the inclination of the plane upon which it has been taken, that from it can be obtained the true position and elevation of points shown on it.

When this point has been reached it bids fair to revolutionize the whole present day methods of topographical survey.

It must not be forgotten, however, that the fundamental basis upon which air surveys are made is a system of triangulation control which fundamentally can never be dispensed with.

This subject is being rapidly developed and the present outline of last summer's operation in Ottawa does not pretend to go further than the experience gained as a result of that experiment.

The field of this subject from a technical point of view is now large and growing rapidly.

The application of aerial photography to obtain topography and the mapping of the earth's surface, has resolved itself into three distinct systems of taking the photographs.

Investigations into these methods are just in their infancy, but considerable progress has been made with some, and reports of results obtained are very encouraging.

This latter remark has reference to the method of taking oblique photographs, and from a control system of triangulation on the ground, at least included in the initial photographs, from which the position of the machine in air is deduced and constants determined for each photograph which will enable the plotting of points in position and elevation which appear in any two photographs in an unbroken series. Reports from Europe are very encouraging; also much is expected in the coming summer when Professor Cook's method is to be tried, and, if these can be relied upon, Aerial Photo-topography will take its place in the front rank of the methods now employed in the mapping of the earth's surface.

The other two methods referred to are more in the nature of means to stabilize the camera. By that is meant some means of retaining the surface of the plate always tangent to the earth's surface, or recording on the plate at the time of the exposure the actual tilt of the plate.

The first of these has for its main object the means by which the camera itself is swung freely in gimbals and the optical axis retained in a vertical position. The other conceives of the camera held rigidly and the inclinations of the plate recorded at the instant of exposure by a stabilized pointer whose position is photographed on the edge of the plate.

The result of these initial experiments has been, as before stated, a rectified mosaic of part of the industrial section of the city along the Ottawa river, and a compiled mosaic of the whole city, unrectified, by Mr. Morgan of the Topographical Surveys branch.

PROGRESS ON THE PACIFIC COAST

G. H. McCallum, Geodetic Engineer, makes the following report on the work of the Survey in British Columbia for the season which has just closed.

The party this year was divided into two direction measurement parties, four lightkeeper parties, a party for preparing stations, the crew of the "Metra" and a storeman at the base camp. The observing parties were in charge of an assistant, who did the observing with a recorder, a cook and a lightkeeper. This number was found sufficient for ordinary stations, but on difficult stations more men had to be attached temporarily to help with the packing. This was particularly the case with the party using the Bausch and Lomb instrument, which, besides being itself much heavier than the Kern, has no vertical circle, and an extra instrument has to be packed to the station to take zenith distances. The substitution of another Kern for the B. & L. will be an advantage in next season's work.

The lightkeepers worked in pairs and usually took turns in running the light and cooking. The senior man was put in charge. On difficult stations they packed their equipment, with about a week's supply of provisions at a time, close to the station and lived there, as it took too much time to return to the shore every day.

The party for preparing the stations consisted of an assistant and two men who marked the stations, built tripods, and cut trails to them in advance of the lightkeepers.

The crew of the "Metra" were the chief of the party, an engineer, a cook and a deck-hand.

The base camp was at Fort Rupert as in the previous season, and stores were sent up there from Vancouver.

The majority of the party left Vancouver for Fort Rupert on May 4, on one of the Union Steamship Company's ships. Owing to the necessity of making repairs, which were not discovered until the last moment, the "Metra" did not leave until about a week later. These were repairs to planking that had suffered from dry

rot. Some planks were found that were quite rotten inside, although apparently sound on the surfaces, and these had to be replaced with new ones. No repairs were necessary however, throughout the balance of the season, and the "Metra" did not return to Vancouver until October 5, after having run a little over five thousand miles, again proving herself to be satisfactory for the work required of her.

Most of the season's work was in the neighbourhood of the entrance to Queen Charlotte sound, and the weather in this district is much the same as in Vancouver. During last season it was very unfavourable for observing. From the middle of May until the end of June it was cold and wet with southeast winds. The wet weather started again the first week in September and it rained steadily during the whole of the remainder of the month. In July and August the weather was fine and dry but the fog, which prevails on this part of the coast, made observing very uncertain. The fog lies out to sea during the day and, in the evening, drifts into the sound, completely closing the lines which run across the sound. Curiously enough the fog is most dense when the barometer is high and it is only when the barometer is falling that there is a possibility of observing these lines.

The new electric signal lamps, of the pattern used by the United States Coast and Geodetic Survey, were employed for the first time on the British Columbia coast last season, and gave very satisfactory results. The lamps were lighted with Edison alkaline storage batteries, which could be recharged on the "Metra" when they were run down. The electrolyte in these batteries is very liable to get spilled when packing the battery to the station and a better device for corking the cells is necessary.

Plans and information were obtained from the Provincial Surveyor-General, relative to a combined traverse and triangulation survey which is being carried on in Fitzhugh sound and the adjacent channels by the Provincial Government, with a view to making connections between some of their stations and this survey.

Owing to a strike of the deck-hands on the coastwise ships sailing out of Vancouver, and to the general shortage of steel barrels with the Imperial Oil Limited, it was very difficult at times to get sufficient fuel to run the "Metra" and this caused some delay.

During the season eight stations were occupied and completed and the work partly finished on two more. The party was disbanded about the end of September and the outfit stored, as before, at Fort Rupert in the care of H. T. Cadwallader.

PROGRESS OF THE SURVEY IN THE PRAIRIE PROVINCES

W. M. Dennis, Geodetic engineer, presents the following report for the field season of 1920:

Returning from the British Columbia coast, after spending some time with Mr. McCallum, who was taking over that work, the engineer arrived in Lashburn, Sask., on June 1, where an outfit was prepared. Here the writer was joined by Mr. McDougall who was to act as assistant.

Leaving Lashburn, the party travelled south, making notes on the adaptability of the topography of the country to primary triangulation. The route lay adjacent to the 110th meridian and passed through Macklin, Alsask, Empress, Medicine Hat and Manyberries. The Milk river was crossed northeast of Sweet Grass, which is on the international boundary near the northern end of the United States Coast and Geodetic Survey's triangulation along the 110th meridian. From this work, which is based on the North American datum, the northern triangulation was to be extended.

Several difficulties were met with in this vicinity. Station "Alma," of the United States Coast and Geodetic Survey's triangulation, was found to be too low to be of any use; the Cypress hills, in reality a level plateau from four to nine miles wide, formed a barrier which had to be avoided, instead of being, as expected, an aid to progress; the Bad Land of the Milk and Lost rivers added to these difficulties

to such an extent that it took almost a month of continuous effort to project the reconnaissance as far north as Medicine Hat, a distance of about 75 miles. During the month of August this reconnaissance was carried to within 40 miles of Calgary, or a further distance of about 125 miles. This chain at present contains nineteen stations and although this reconnaissance was of a preliminary nature, seventeen of these stations may be considered satisfactorily established.

The latter part of the season, after September 11, when triangulation reconnaissance was concluded, was spent in looking over new territory, preparatory to operations in 1921. The country north to Vegreville, via Wetaskiwin, and east to Lashburn, was covered and a trip made to the vicinity of Cold lake.

It seemed of primary importance, at the outset of this work, to test ordinary methods of reconnaissance as applied to flat country, to find what special equipment, if any, would be necessary, and to estimate the cost of Geodetic triangulation for the Prairie Provinces, as compared with that for the provinces of more varied topography.

Method and equipment.—Usual methods and equipment were found quite satisfactory, but it is essential that the latter should contain the portable tower and an auto truck capable of a speed of 30 miles per hour. A plane-table and folding sight alidade will be found of great advantage.

Cost.—In general, the topography in the territory traversed is suitable to the projection of primary triangulation if the length of lines is held to approximately 25 miles. This has also the advantage of reducing the cost of tower building, which will probably be much less than anticipated.

Only three towers, it is expected, will be required on the nineteen stations previously referred to, but it must be remembered that any conclusions drawn from this are only applicable to the section of Alberta south of Edmonton. Our knowledge of the other sections, with respect to their adaptability to triangulation, is not yet sufficient to warrant a definite opinion as to the cost of towers in other parts of the Prairie Provinces.

The cost of triangulation, as would be expected, will increase somewhat with the latitude of the district, as timber, muskeg, and the difficulties of transportation increase as one goes north.

In general it is expected, on account of favourable weather conditions, that the cost of angular measurement in the Prairie Provinces, is likely to be considerably less than in other parts of Canada, but that the cost of marking stations, usually negligible, will be somewhat greater here as almost all points will require subsurface marks and reference monuments. However, as the cost of angular measurement is usually far in excess of all other operations any saving of time on this will reduce considerably the total cost per station, of the completed work.

The future will develop a large demand for geodetic work in this western territory; unit cost will depend largely on transportation expenses; hence it is very advisable that the type of motor equipment be purchased in the beginning which will be most suitable and economical for use as operations expand to fill requirements.

PROGRESS OF THE WORK IN SOUTHWESTERN ONTARIO

A. M. Grant, Geodetic engineer, submits the following report:

Work in Southwestern Ontario during the season of 1920 was carried on in three separate districts. Primary and secondary triangulation near Goderich, the triangulation of the city of London, and primary work south of Owen Sound.

The first work was the completion of the primary triangulation, in the vicinity of Goderich, and the making of a connection from the latter to the shores of lake Huron.

A very violent storm which swept over the whole of western Ontario on November 29, 1919, blew down about 90 per cent of the towers of the Survey, and made the completion of the work very difficult.

Only one primary station, Hay, had to be occupied to complete the primary work in the vicinity of Clinton and Goderich, and one tower, Hullett, had to be rebuilt. A decision had to be made as to whether it was more economical to put in a figure with high towers, to make the connection with lake Huron, or have more stations with shorter lines and avoid high towers. An examination of the country showed that an extension from the line Hay–Hullett could only be made by means of high towers, but from the line Morris-Hullet, where the ground was rolling and broken up by deep ravines, a scheme of secondary accuracy could be carried forward without any expense of towers. As the net in question terminates at lake Huron a short distance from Hay, a secondary triangulation is considered serviceable. The observing on this scheme was partially completed by Mr. MacTavish when it was necessary for him to move farther north.

The next work was the triangulation of the city of London on which reconnaissance work was started on July 20. There were four primary stations surrounding London, viz: Lobo, Westminster, Biddulph and Nissouri. All were used in stepping down from the primary triangulation to the shorter lines in the city of London. The sketch on page 27 shows the connection with the primary work.

As the storm mentioned above had blown down all four towers, this connection was not as strong as it would have been had they been available. No observations could be made at either Lobo or Nissouri without the building of 70-foot towers and the extra strength was not considered worth the extra expense of the towers.

The four new stations, Girvan, Odell, Springbank and Hunt, formed a quadrilateral around London from which the positions of the various points in the city were obtained. Sketch on page 27 shows these points so selected and their relation to the city boundaries. The direction and angle measurements on this work were made by Mr. J. M. Riddell.

During the course of the season's work much valuable information was obtained on the progressive twist of the towers. This twist was in one direction when the day was hot and the sun shining, and in the opposite direction after sunset, and sometimes reached a magnitude of one minute of arc in half an hour. It is hoped that much more information of the same nature will be obtained next season, so that conclusions may be arrived at, which will be based on observations covering several years.

HORIZONTAL DIRECTION MEASUREMENT IN SOUTHWEST ONTARIO

W. H. McTavish, Geodetic Engineer, reports as follows on the observing which was carried on in western Ontario during the field season of 1920.

The work in this district, during the first part of the season, was carried on by a party of five men and later by a party of six men. These were an observer, a recorder, a cook and three lightkeepers.

A terrific windstorm, in the late fall of last year, played havoc with the towers throughout western Ontario. It is probably safe to state that 90 per cent of the towers were blown down during this storm which was not confined to any small area. For the most part, the office was advised promptly of the destruction of these towers.

Before any observing could be done, the tower at Hullett had to be rebuilt. The destruction of this tower had not been reported to the office, so we were in the field without the necessary tackle for tower building. In its absence the tower was built piece by piece to a height of sixty feet. This was accomplished in five days by a party of four men. During this time, Mr. A. M. Grant, who was in general charge, transported daily in his Ford runabout the observing party from their camp at Hay, twenty miles distant.

The portable tower, which plays a very important part in the western Ontario work, since so many of the towers have blown down, was erected in turn at Biddulph and Hibbert and the angle measurements were made at Hay.

During the month that the observing party was at Hay, Mr. Grant and the writer did reconnaissance in the district between Clinton and Goderich, the object being to project a secondary triangulation scheme to points near the shore of lake Huron which were to furnish control for the Department of Naval Service.

Towards the end of June, the observing party moved to Hullett, where it remained until August 18. During this time the stations Hullett, Blyth and Auburn were occupied. Also, the sub-surface and surface marks were put in at the above stations, as well as the stations Carlow, Chambers and Benmiller. Considerable difficulty was experienced in procuring cement for this purpose.

After occupying the station Morris on August 19 and 20, the observing party as well as the two lightkeepers moved about twenty-five miles north to the primary station Carrick. Here the tower which had blown down was rebuilt by using the material of the old tower for the purpose. The tower was hoisted in the usual manner into position by means of a Reo truck with which the party was provided about the first of August. Mr. Grant directed the building of the tower which occupied the time of five men for a period of six days.

As soon as the tower was completed, lightkeepers were stationed at Bentinck and Egremont, and Carrick was occupied. During the week occupied at Carrick the lights at Egremont and Bentinck were visible on three nights but they could be seen only in the absence of illumination in the field of the telescope.

The tower at Egremont was thought to be in an unsatisfactory condition. On September 6 the observing party exchanged places with the lightkeeper there in an effort to get some observations before the end of the season, but on account of very poor atmospheric conditions no success was met with.

The party was disbanded on September 13.

OPERATIONS IN CONNECTION WITH THE TRIANGULATION OF LONDON, ONTARIO

J. M. Riddell, Geodetic Engineer, submits the following report on work in connection with the triangulation for the city of London, Ontario.

Proceeding to London on August 13, some time was spent in co-operation with Mr. A. M. Grant in studying the general scheme and opening up several lines which were blocked by trees.

The scheme as laid out by Mr. Grant consisted of a main quadrilateral surrounding the city, viz., Springbank, Odell, Hunt and Girvan, from which all the points in the city necessary to control the precise traverse work were cut in. The greater part of the observing for this work was done during the day on signals, but in order to obtain as high a degree of accuracy as possible in locating Springbank, all directions to and from the primary points were observed at night with the usual primary accuracy.

Observing commenced at Springbank tower on August 24, with a Stiegel 12-inch direction instrument. This instrument has a very large eccentric error of over one minute and proved very confusing at first; however, the results finally obtained were quite satisfactory.

High winds during the day made it impossible to obtain consistent results on intersection points from Springbank and it was found advisable to continue with the observing at other stations after the primary directions had been observed, returning to Springbank on a perfectly calm day to finish the secondary directions. Smoke and haze were also responsible for delaying the progress of the observing. On October 2 the telescope of the Stiegel instrument was taken to the Consolidated Optical Company in Toronto and the wiring on the diaphragm was changed from the vertical lines to the diagonal, a change which proved to be a much more satisfactory arrangement for observing on the signals.

The observing was finished on October 26. In all there were five stations occupied with the 12-inch Stiegel direction instrument with a total of seventeen primary and thirty secondary observed directions, and nine secondary stations occupied with the 6¼-inch Berger repeating instrument with a total of seventy-nine measured angles, in addition to various connections to reference monuments and lot corners.

The results have shown a very high degree of accuracy, well within the limits set for primary triangulation. No triangle whose three angles were measured with the Stiegel instrument has a closing error of over 1 second, and in only two triangles where the angles were measured with the Berger instrument did the closing error amount to more than 3 seconds.

The various stations were marked with surface and sub-surface points consisting of a copper wire set in a tile filled with concrete; wherever possible the stations were referenced to lot corners or a reference monument.

RECONNAISSANCE ALONG THE SAGUENAY

J. A. H. Henderson submits the following report on reconnaissance work along the Saguenay.

In May, 1920, I proceeded to the Saguenay river and from May 19 to September 18 was engaged in carrying out instructions to make a reconnaissance for primary triangulation commencing from the St. Simeon-Tadoussac line of the St. Lawrence River system and proceeding up the Saguenay river.

In this connection it was thought advisable to cover the extremely rough, mountainous and mostly uninhabited country between the St. Lawrence river and Chicoutimi as quickly as possible by putting in, in this region, a system of primary triangulation.

This area was covered by two quadrilaterals.

Stations were located in the townships of Labrosse and Chardon, on the north side of the Saguenay river, and in Ducreux and Ferland, on the south shore. The elevations of these stations above mean sea-level were approximately: Labrosse, 1,900 feet; Ducreux, 2,500 feet; Ferland, 1,350 feet; and Chardon, 2,900 feet.

The country covered by this system is of an extremely mountainous nature and very rough. It is most sparsely settled and in these settlements farming on a small scale is carried on in a very old-fashioned manner.

The great industry of this region is lumbering, timber being cut for both lumber and pulp and papermaking. Large mills for these purposes are located at Ha Ha Bay, Chicoutimi and Kenogami; some smaller mills at other points along the river.

From Ha Ha Bay up river the country is more open, level and suitable for agricultural purposes. From Chicoutimi to Lake St. John there is an excellent farming country which is noted for its dairying. It is fairly level and well settled and it was for the benefit of the present residents, with a view of attracting more to this country that the Provincial Government of Quebec desired to have Geodetic control to enable correct and suitable maps of this region to be obtained.

The lower part of the Saguenay was suited for the primary triangulation; so is the upper part from Chicoutimi to lake St. John suited for secondary work and that is the prospect for the continuation of this reconnaissance up to, and around, lake St. John.

Astronomical stations had been previously located and observations made at both Chicoutimi and Roberval and these as well as the existing survey of the country and township lines, will be tied into the system by triangulation methods.

RECONNAISSANCE OF THE LOWER ST. LAWRENCE

Professor Louis B. Stewart submits the following report of reconnaissance on the lower St. Lawrence made during the season of 1920.

The writer left Ottawa on May 21, reached Matane the following morning, and secured a passage to Mount Louis, landing there on the 23rd. Mr. Rose had been there a week, and had located by a process of elimination, the probable position of the hill seen last fall from Mount Edward.

On the 25th the party climbed this hill, which is situated a mile or two to the west of St. Pierre village, and found, as expected, that it commands a view of Mount Edward. A hydrographic survey party from the "Cartier" in charge of Mr. Bowes, was engaged in building a signal about a quarter of a mile from the point situated for the Geodetic station, and on Mr. Bowes' invitation the party went on board the "Cartier."

The following morning the "Cartier" moved on easterly, landing the party in company with Mr. Bowes' party. Climbing the hill, near the village of St. Antoine, picked out the previous day as a likely one for the next station, the parties respectively located stations at the same spot at a height of nearly 1,800 feet.

The following stations were then located in the order named: Cloridorme, Fame, Gaspé, Ross and Percé, each following naturally from the previous one, as being the only available point suitable for a station. Some of the lines between these stations are short, an objection that might be removed by selecting points further inland. Stations so placed, however, would be difficult of access, and useless for locating points near the shore.

The stations, Gaspé, Ross and Percé are expected to form a quadrilateral with a station near the mouth of the Jupiter river, on Anticosti island, where a height of about 400 feet will be necessary. Weather conditions while at Percé prevented seeing Anticosti, but on visiting that island later, it was decided that there would be no difficulty in finding a point of the required height.

On June 25 the party left Percé and travelled by rail to Rimouski, and on the 29th crossed the river on the "Gulnare" and landed about a mile and a half west of Pointe Des Monts. After building a tripod 22 feet in height at the point selected for a station last summer near St. Augustin cove, the party moved to Trinity bay.

Here considerable difficulty was experienced in finding a point visible from Augustin station, and at the same time commanding a view of Cawi island, or some point in its vicinity. By July 9, it was thought a point fulfilling requirements had been found and on the arrival of the "Gulnare" therefore, on the 14th, to test the line, the party ran to Cawi island, selected the position for a station, left Mr. Clark to show light and helio there and returned to Trinity bay, when the "Gulnare" left for Rimouski to coal.

The result of the test was to show that the line was not open, so another hill was finally chosen, about two miles northeasterly from the first. This change made it necessary to shift Augustin station about a quarter of a mile farther north, but the new position for Trinity station commanded a view, not only of Cawi island, but also of the higher Sproule point on the mainland, where the next station was placed; moreover, it lengthened the line Augustin-Trinity by about two miles.

On the return of the "Gulnare" on the 23rd we set out for Seven islands, stopping en route and establishing the station at Sproule point, at the same spot as had been used for a station by the Hydrographic Survey. A landing was made and camp pitched near the Clark city wharf.

The primary station here was placed on the summit of Great Boulay, the highest of the islands, again using the same point as had been selected by the Hydrographic Survey; and this was the most easterly of their stations met with. A secondary station was also established on the high promontory on the west side of the entrant to Seven Islands bay, to which the name Arnaud, that of the township was given.

A few miles to the west of the Sheldrake river the maps show an elevation of 700 feet; but, while there may be heights as great as that several miles farther inland, there are none near the point where the figures occur on the map. The best hill for our station, a height of about 380 feet was selected. It is situated about six miles west of Sheldrake, and a mile west of Green cove, from which it can readily be reached.

A question at once arises as to the visibility of points on the south shore from this station. A computation based upon the normal value of the coefficient of refraction leads to the conclusion that at least one is not visible. The fact was noted, however, at Bersimis and elsewhere, during the previous season, that lights on the opposite shore were constantly visible under conditions that pointed to an abnormally large value of the coefficient of refraction on lines crossing the St. Lawrence. While at Sheldrake, therefore, a number of determinations of that quantity were made by means of observed angles of depression of the sea horizon at a point of known elevation, and values varying between 0.11 and 0.31 were obtained, the mean being 0.226. When more than one determination was made on any one day they also showed an increase towards the end of the day in nearly every instance. Computing the value of the coefficient necessary in order that the stations Sheldrake and Cloridorme may be intervisible, it was found to be 0.15, so that it is reasonably certain that the line between those stations will be open; and that is the only doubtful line.

While at Sheldrake a station was also established on the end of a gravel ridge about two and a half miles easterly from Thunder river. The party then set out for the Mingan islands and Eskimo Point in a small sail-boat with auxiliary power owned by Mr. Wm. Girard, of Jupitagan. The first choice of the next station was on Inner Birch island, the highest of the Mingan group, with possibly the exception of Large island. From what was found subsequently on Anticosti it may be advisable to move this station to Mingan island.

During the night of August 16 the boat was anchored beside Birch island, after a wet and foggy day. The morning of the 17th was unusually clear, however, and a couple of hours was sufficient to find the highest point on the island and mark the spot; the party set out at once for Eskimo Point, reaching it by 2 p.m.

At the telegraph office at Eskimo Point it was found that the "Gulnare," with Mr. Rannie on board, called at Mingan, and had left for the Anticosti shore and St. Nicholas. A telegram from Mr. Rannie contained instructions to go to Anticosti before establishing a station near Eskimo Point, and make a reconnaissance there for a base net connecting a projected base with the main triangulation scheme.

Upon arrival at Ellis Bay, a small building about twelve miles from the settlement, on the railway line, was placed at the disposal of the party by the administration, where headquarters was established, as it occupies a convenient central position with regard to the base net. A hand-car was also loaned, which proved of great service in moving from point to point. Appreciation of the uniform kindness and courtesy shown by the administration of the island in placing everything at the disposal of the engineers that could be of assistance in the work is here expressed.

Having picked up the base line on the ground by the help of a description wired by Mr. McDiarmid, a careful examination of the surrounding country was then made, which resulted in the location of a station to the north and another to the south of it, forming with it a quadrilateral, commanding a sufficient view of the north and south shores of the gulf. A station was also established on a hill near Grand McCashty, which serves as an additional connecting link between the base and the stations on the main shores, commanding a most comprehensive view in nearly all directions. In an attempt to locate the next station easterly a trip was taken to the mouth of the Bicacie river, about eighten miles from Ellis Bay on the south shore of the island. A likely hill seen from North station lay about five miles farther on and two or three miles back from the shore; this was not reached as time did not permit. The high ground near the Jupiter river was also clearly visible, about thirty miles distant.

Before finally adopting the position for North station, as located on the ground, it will be advisable to test the lines between it and Cloridorme and Fame, as the air was never found clear enough to insure the visibility of the stations on the south shore.

Determinations of the magnetic declination were made at several points.

On September 21 the party left on the steamer "Savoy" for Quebec, thus bringing the season's work to a close.

TRIANGULATION OF LOWER ST. LAWRENCE RIVER AND GULF AREA

W. C. Murdie, Geodetic Engineer, reports as follows:—

This season's work covered that portion of the Lower St. Lawrence river and gulf from Bicquette Island lighthouse to Cap Chat lighthouse, a distance of approximately one hundred and fifteen miles. As a result of the progress made this year the primary triangulation net has been extended eastward towards the gulf so as to give a primary control over approximately six thousand square miles of land and water.

The area worked over comprises a strip along both the north and south shores of the Lower St. Lawrence river and gulf. Generally speaking, the north shore portion is rough and undeveloped. Certain parts are rocky and sparsely covered with a poor quality of spruce, balsam, etc., while other sections, generally speaking, farther inland, are covered with marketable timber. The principal industries are lumbering (pulpwood), and fishing, while a certain amount of revenue is derived from trapping furbearing animals. Within the past few years large American companies have commenced developments in the lumbering industry.

The south shore portion is settled. The main industry is farming, but some good timber still remains standing at some distance back from the St. Lawrence. This timber is cut and driven down on the tributaries of the St. Lawrence.

During the summer months there is no communication on the north shore by land from Laval bay eastward. To offset this disadvantage the C.G.S. "Gulnare" was employed to move the various parties from point to point as required. In view of the fact that the width of the St. Lawrence where work is being done is not less than thirty miles, with very few harbours, a stable and sea-worthy boat is required to combat frequent storms.

The organization was as follows:—

Land parties—

(*a*) Two parties to make the geodetic measurements and observations comprising: engineer-in-charge, recorder, helper, cook.

(*b*) Five lightkeeping parties, comprising a lightkeeper and helper to take charge of searchlights at all out-of-the-way stations.

(*c*) Two one-man lightkeeping parties who attended to stations near civilization.

(*d*) One tower-building party made up of engineer-in-charge, carpenter, two or three labourers, as the situation demanded. (Engaged locally).

Ship Party:—

C. G. S. "Gulnare".—Length, 137 feet; breadth, 20 feet; draft, 13 feet; with crew of six officers and eighteen other ranks.

The field season extended from May 7 until October 7.

Three men forming the first section of the land party went under canvas at Trois Pistoles on May 8, 1920, to prepare camp for the second section. This second section, including Messrs. Ney and Kihl, engineers-in-charge of instrumental work, together with fifteen recorders, cooks, lightkeepers, etc., reached Trois Pistoles on May 12. During the following week equipment was taken from storage, overhauled and distributed to the different parties; lightkeepers were given concentrated training in the use of the helio and lamp (both acetylene and electric). The fact that several of the lightkeepers were ex-army signallers or previous employees of the Geodetic Survey made training easier and gave much better service.

North Shore Party.—On May 17 Mr. Kihl, with two assistants and a cook, with a combined purpose of reconnaissance and station preparation, left for Leclerq primary geodetic station in the Shickshock mountains. The party travelled to Matane by rail, thence by wagon over difficult roads for a distance of approximately forty miles. Streams were swollen; considerable snow still lay in the wooded lands; the frost was coming out of the ground and the combined effect made travelling slow and

very difficult. Four hundred pounds on a single wagon was considered a fair load for a horse. The wagons proceeded to within a distance of approximately eight miles from the foot of the mountains in question.

From the end of the wagon road a trail had to be blazed and opened up to the station. Two bridges over fast mountain streams were made. To get from the foot of the mountain to the station there was a climb of approximately 2,350 feet. A considerable part of the climb was over several feet of soft snow. The upper one thousand feet of the mountain was covered with a very dense growth of wind-beaten scrub spruce, etc., necessitating difficult cutting in order to open up a passage. This latter was absolutely necessary in order to take a lightkeeper's outfit to the station, as in many places, owing to the density of the brush, it was almost impossible to make headway, even when travelling light. The trip to and from Leclercq geodetic station consumed nine days, five of which were spent in travelling.

Upon the return to civilization Mr. Kihl proceeded to establish Val Marie geodetic station. Hazy and smoky weather made progress difficult, with the result that several promising yet difficult mountains had to be visited before securing the best location. A fifteen foot tower was built.

The third station to be established and prepared was Manicouagan, on the north shore. At that point Mr. Kihl erected a 25-foot tower.

The reconnaissance and station preparation work having been completed, Mr. Kihl occupied Bersimis primary geodetic station on June 18.

South Shore Party.—On or about May 22, the south shore party, under the direction of Mr. Ney, commenced work at Bic primary geodetic station.

At the end of June it was found necessary to put a tower building party, with Mr. R. S. Talbot acting as engineer-in-charge, in the field to prepare advanced stations along the Gaspé coast. Mr. Talbot kept one assistant with him continually and picked up other necessary help locally.

The C. G. S. "Gulnare" was taken over on April 1 from the Department of the Naval Service. Almost immediately necessary repairs, etc., for the summer season were commenced and executed. Ships stores for deck, engine-room, and stewards' departments were arranged for and the "Gulnare" sailed from Halifax for Rimouski on June 5. The crew of the "Gulnare" included six officers and eighteen other ranks.

The "Gulnare" arrived in the gulf just at the time when the land parties on the north shore had proceeded as far as it was possible to do so without the aid of a boat. The work of the "Gulnare" was to move parties from place to place as required and to keep them supplied with equipment, food, etc. On account of the north shore being rough and unsettled and without communication by land it is not possible for parties to obtain food or supplies locally, nor is it possible to obtain anything like satisfactory transport by boat locally.

The "Gulnare" being a substantial sea boat made it possible for parties to be moved when desired, thereby eliminating lost time. At the same time it was not necessary to run for shelter to obtain cover from approaching storms. It may be mentioned that harbours are scarce on both the north and south shores in the area worked over in the season of 1920, and for this reason the matter of safety was an important factor.

The weather conditions throughout the season were varied. Haze, smoke and rain all tended to retard progress of the work. Horizontal refraction was quite prominent and had its retarding effect on the rapidity with which a station could be successfully completed.

The results of the season's work are as follows:—

North Shore Party—	
Stations occupied	4
Stations located and prepared	3
Towers built	3
Piers erected	3
South Shore Party—	
Stations occupied	6
Towers built	1
Land survey points tied in to geodetic stations	4

Tower Building Party—

Stations prepared	3
Towers built	3

From primary stations occupied the following observations were taken, in addition to those on primary stations—

On lighthouses	26
" Churches	12
" Supplementary stations	2

The following benefits will result from this season's work:—

1. The Surveys Department of the Government of the province of Quebec will benefit from having the co-ordinates of several primary geodetic stations, together with lighthouses and churches. These stations are located on prominent hills or mountains while lighthouses and churches are certain to be in the centre of some important area.

2. Hydrographic Survey reference marks have already been, and others may easily be, tied to Geodetic Survey stations and thereby have their co-ordinates derived.

3. Leclercq primary geodetic station is situated on one of the most prominent mountains in the Shickshock range and may be within ten miles of the line of the proposed railway through the interior of Gaspé.

4. In many places towers have been built by the Geodetic Survey. These towers are, needless to say, on the most prominent points and from them good views can be had of the country for many miles in all directions. Well beaten trails are made leading to these towers. These ought to be very useful for fire protection associations.

RECONNAISSANCE IN NEW BRUNSWICK

J. W. Menzies submits the following report of reconnaissance surveys in the province of New Brunswick.

The purpose of this reconnaissance is to locate a system of triangulation as close to the east coast as possible that will connect up the system along the bay of Fundy with the system which is being extended along the valley of the St. Lawrence river. During the latter part of the season of 1919 a start was made from the line Shepody-Salem in the Bay of Fundy system and progress made as far as the line Indian–West Point.

From Indian mountain north the country is made up of flat ridges running generally from east to west. Another feature of the topography is that the ridges for a distance of about fifteen miles inland as a rule are higher than those further inland. As a consequence the location of the stations presented some difficulties and the lengths of one or two of the lines are not as long as one would wish. Owing to the wooded nature of the country towers will be required at all points located this season.

Owing to the difficulty of judging distances accurately in flat country one or two of the lines will have to be tested by lamp before it is quite certain that the lines are open. The engineer is not sure that the lines St. Fabien–St. Ignace and Lakewood–Ashton are open. To test these lines towers will first have to be erected at St. Fabien and Lakewood. If they are not open intermediate stations can be put in that will connect up with the rest of the system.

At the close of the season barometric measurements for height were taken at Botsford on the mainland and West Point on Prince Edward Island. The results showed that with a fifty-foot tower at West Point and a twenty-foot tower at Botsford the two points would be intervisible. Next season it is hoped to ascertain by the same method if it will be possible to open the line Eel river to West Point. If this is possible it will considerably strengthen the triangulation up to Eel River station.

From the line Nipisiguit–Red Pine northward the topography is of a more varied nature and the reconnaissance will probably not be quite as difficult. However the transportation facilities will not be so good. In fact from the line Ashton–Chatham northward the roads are very scarce.

The weather retarded the progress of the work very much. Up to August on the whole it was satisfactory. In August haze was very prevalent and in a country composed of flat ridges it is practically impossible to get satisfactory results under these conditions. In September rain was the disturbing factor. During this month there were only about six days that were clear enough to take the necessary compass readings. This rainy weather continued into the first ten days of October.

The new type of portable tower was of great assistance during the season. In fact at certain stages the work could not have been done without it. The tower is composed of two sets of ladders (see Plates I, II, and III, inside back cover) which rest on sleepers and are about twenty-three inches apart. The sets are maintained at this distance by braces every five feet and the whole tower is held by four sets of guys at points twenty-five feet, forty feet, fifty-five feet and seventy feet high.

These ladders are twelve feet in length, about twenty inches wide at the bottom, and about seventeen inches wide at the top. This difference in width allows them to fit into one another with an overlap of two feet so that each ladder gives ten feet in the clear. Two shorter lengths, seven feet long, are also supplied. Allowing for the two feet overlap they give five feet in the clear. In building the tower one of these is placed at the bottom of one of the sets. By this means one side is always five feet ahead of the other, and on this fact depends the principle of erection. In turn on the top of each extended five feet a small swinging crane is placed and by means of a rope and pulley the ladders are successively raised and placed in position.

On the long ladders the fourth, seventh, tenth and eleventh rungs are two inches longer on each end than the others, for attaching the above mentioned braces. The first and eleventh rungs are made of steel tubing in order to take the weight of the ladders.

The hoisting rope is two hundred and fifty feet long and one half inch in diameter. The hook is placed one third of the distance along the rope and the long end is then threaded through the pulley and becomes the hoisting end of the rope. The short end is used to guide the ladders up and down.

The guys are also of half-inch rope and in the following lengths: seventy, ninety-two, one hundred and five and one hundred and thirty feet. There are four of each length, and pieces of string are wound around the ends of the ropes to indicate the set to which they belong. Thus the seventy-foot lengths have one piece of string wound around the end of each rope, the ninety-two-foot lengths two pieces and so on. Clove hitches with a couple of turns on the standing end were generally used when tying on. When puting the clove hitches on the rungs it will be found best in making the first loop to pass the running end between the standing end and the side of the ladder. The knot can then be easily loosened with the strain on the rope.

The pickets, fifteen in number, are made of steel rods forty inches long and about half-inch in diameter. The first set of guys is tied to the first set of pickets. The second and third sets are tied to the second set of pickets and the remaining guys to the third set of pickets. There are four extra guys supplied, three-eighths of an inch in diameter and one hundred and fifteen long. These are supposed to be used as torsion guys when precise readings are taken but as these were never necessary they were only used at times as auxiliary guys during erection.

The tower stands on two wooden sleepers, each of which has two short steel rods bolted to it. The mortised ends of the lower ladders fit onto these rods. These sleepers are placed at right angles to the wind and they should be fairly well levelled up as it is much easier to keep the tower plumb if this is done.

After placing the sleepers, lay out and connect up three full lengths of the ladders. On the opposite side, lay out and connect up one short and two full, having the short length on the bottom. Having placed the ladders so that they can be swung on the steel rods on the sleepers, attach the pulley to the top steel rung on the short side. Then to the rung at the same height on the other side attach the hook, or better still double the rope and tie it on. Next place the first set of guys on the same rungs to which the hook and pulley are attached. The pickets are placed on line

with the diagonals of the rectangle formed by the sleepers. The proper distance can be determined after a few trials.

To raise the first sections one man stands on the sleepers and pulls on the long end of the hoisting rope. At the same time the other man raises the short side first. After raising it a certain distance the man on the rope can pull it up the rest of the way as the weight of the thirty-foot side is sufficient to overcome the strain on the hook. This side is pulled up until it is almost perpendicular. As mentioned before, after a few trials, the proper place for the pins and the necessary lengths of guys for the ladders to come to this point will be ascertained. The second man now raises the thirty-foot side a short way and it can be pulled up the rest of the way using the twenty-foot side as a gin pole.

The necessary braces are now put on and the crane placed in position on the long side. Three holes are bored in each brace. The first hole is used to fasten two braces with pins to both sides of the tenth rung of the ladder before it is raised. When the ladder is placed in position the second hole is used to fasten the brace on to the corresponding rung on the other ladder. The third hole, thirty inches from the first, is used to hold the brace to the ladder at the seventh rung, when raising or lowering the ladders; in practise this was not always carried out. When putting on the braces always see that the pulling end of the hoisting rope runs down the centre of the tower. The pins for holding the braces on are made of fairly stiff wire looped at one end to prevent them falling through.

From this point on the erection is straight forward, due attention being paid to keeping the tower plumb. In raising the guys they should be attached to the top steel rung of the ladder whose top will be fifteen feet above the last set of guys put on. When this ladder is in position the guys can be attached to the proper pegs and the next ladder raised. After this ladder is in position two of the guys can be shifted to their proper position on the ladder last raised. This procedure saves time and contributes to the safety of the man on the ladders.

When taking compass readings the crane is lowered just enough that the steel will not interfere with the needle; it is also advisable to keep the compass as far as possible from the steel rungs. The crane has also to be removed if the top platform is going to be put on. This platform fits on top of the ladders and has a hole cut in the centre to allow the observer to stand with his head and shoulders above the top; it folds up for carrying purposes.

When taking the tower down the procedure is exactly reversed except that the guys may be thrown off entirely at each point as it is reached instead of lowering them with the ladder. When lowering the twenty-five and thirty-foot sections it is advisable to have a ladder resting on its side so placed as to prevent the sections coming to rest flat on the ground, thereby obviating the risk of splitting the lowest ladders where they mortise on the sleepers.

Under favourable circumstances the tower can be raised by two men in about one hour and three-quarters and taken down in about one hour. The difference in time between lowering and raising is due to the time taken up in attaching the guys. In windy weather raising the tower is a somewhat difficult task as each ladder is raised on the leeward side and then has to be swung into place against the wind.

The Reo truck proved a great help in quickly transporting the tower from place to place in order to take advantage of good weather; a considerable saving in time and money resulted from its use.

A diagram of the proposed triangulation from the line Shepody-Salem is shown on page 10.

PROGRESS IN RECONNAISSANCE IN NOVA SCOTIA

H. P. Moulton, Geodetic Engineer, submits the following report covering reconnaissance surveying in Nova Scotia during the past season.

Early last spring plans for the extension of triangulation eastward in Nova Scotia were completed, and with Mr. W. N. McGrath as assistant, the engineer left Ottawa during the latter part of April for Truro, N.S.

A provincial law in Nova Scotia prohibits the use of automobiles over the country roads earlier than May 1. Accordingly on that day a start was made from Truro for Antigonish, where actual field work commenced.

The first point located was a supplementary station on a sugar loaf (750 feet in height) about two miles from Antigonish. This point required a thirty-five-foot tower, from which most of the buildings in Antigonish, including St. Francis Xavier University, and also a number of lighthouses on George bay, are plainly visible.

In order to connect with the Hydrographic Survey triangulation on the Atlantic coast, three primary stations were next located in Guysboro county. Two of these stations, Salmon and Fox, are coincident with stations of the same name established by the Hydrographic Survey. Copper bolts set in rock preserve the exact location of these points.

The remainder of the season was spent in Cape Breton; and the triangulation now covers all the western end of the island and the Bras d'Or lakes, the most easterly points being in the vicinity of the Sydneys.

The presence of many parallel ridges of fairly even elevation presented some difficulties to the Reconnaissance Survey but the greatest hindrance to the progress of the work was the prevalence of extremely hazy and foggy weather.

Transportation during the whole season was effected by means of a Chevrolet car, which gave very good satisfaction.

The season's work covered an area of about five thousand square miles. In all sixteen stations (eleven primary and five supplementary) were located. Six of these points are ground stations and the remainder require towers of an average height of about fifty feet. The average length of primary lines is twenty-eight miles. The northerly stations have an average elevation of about eleven hundred feet and southerly stations about seven hundred feet.

Station Moyac (near Arichat, C.B.) was chosen as an aid to secondary work in that section of the province. The line Moyac-Fox will form a good base, should a secondary scheme be required to cover Chedabucto bay and the strait of Canso.

The line Derby-Marble will also afford a good base for secondary triangulation on the Bras d'Or lakes.

The triangulation eastward from the line Londonderry-Barr, of the Bay of Fundy net, is exceptionally strong. The value R, (Where $R=\frac{D-C}{D}\Sigma[\delta_A^2+\delta_A\delta_B+\delta_B^2]$) through the best chain of triangles (sixteen in number) and covering a distance of 168 miles is only 32.5 and the value R_2, through the second best chain is 84.7.

The owners of the land on which the stations are located, were very pleased to have observing towers erected, in many cases wishing that they were built higher on account of the beautiful view afforded by them. The scenery in Cape Breton is without rival in Eastern Canada.

MEASUREMENT OF HORIZONTAL DIRECTIONS IN THE MARITIME PROVINCES

Claude H. Brabazon, Geodetic Engineer, reports as follows:—

In accordance with instructions, the writer, who had again been placed in charge of a party to continue the measurement of horizontal directions in connection with the Geodetic Survey in the Maritime Provinces, left Ottawa for Truro, N.S., on May 6, arriving there next evening and on the eighth drove out to Onslow for the camp outfit and motor-truck which had been stored there with a farmer the previous fall. Everything being found in first-class condition, no time was lost in again getting under way. En route from Onslow to Camden two men and a cook were picked up at Truro, supplies and gasoline were procured, and by nightfall camp was made within easy reach of Camden, which was to be the first primary geodetic station occupied.

Training Lightkeepers.—The training given lightkeepers in the duties required for their special work, at the beginning of last season, proved so satisfactory that it was decided to continue the system this year, consequently, the men were notified to report at Camden, and as they assembled they were instructed in the use of the signal code, signal lamp, etc., as a result of which the work of the lightkeepers throughout the season was in every way efficient.

Commencement of Operations.—The lightkeepers with complete outfits had been placed at their respective stations and on the eighteenth when Camden was first occupied all lights were showing. Some delay was occasioned on account of the lines Camden–Eastville and Camden–Dalhousie being blocked by a heavy green hardwood bush covering a high ridge about five miles distant; this presented a rather formidable barrier; however, the difficulty was overcome as follows:—

The course to Eastville having been calculated from the map, a big dry tree was sighted in line on the ridge, which was fortunately found with but little trouble, and when a vista had been opened a clear view of the light on Eastville was obtained, and thus the necessity of cutting trial lines through this heavy bush, which would have been a slow and expensive operation, was obviated. The latter line, Camden–Dalhousie, was easily cleared, as the bush which caused the obstruction was quite close to the former station.

On May 25, Mr. J. E. R. Ross, D.T.S., called at Camden on his way to Nutby, to discuss with the writer, among other things, methods of co-operation which would ensure the greatest measure of success for the summer's field work.

Northumberland Strait Region.—In extending the triangulation from Camden, along the strait to the eastern end of Prince Edward Island, the writer occupied the following primary stations, Eastville, Dalhousie, Pictou Island, Caledonia, and Red Point. This completed the measurements in the Northumberland strait net to the line Red Point–McDonald, and terminated the season's operations.

From the primary stations, and from supplementary points which had been located along the coast, measurements were taken on lighthouses, church spires, domes of buildings, water tanks, etc., which were thus established as control points for the hydrographic and other surveys.

General Remarks.—During the season's operations an area of more than 4,000 square miles was covered, and it might not be amiss to note here that within its limits there is magnificient scenery in endless variety. The lakes and rivers teem with fish, and game both large and small, abound throughout the mountain regions. While weather conditions were not as favourable as last season they were as good as the average. In the eastern provinces fog is responsible for slow progress, especially in the early summer months. The motor-truck was of the greatest advantage, and again proved its worth by saving time and money in getting the engineers and camp moved quickly from place to place.

Close of Survey.—The lightkeepers having been signaled "season's work completed," left their respective stations for home. The camp equipment and motor truck were stored with a farmer at Green Hill near Pictou, N.S., and the writer returned to Ottawa the following day October 15.

SUMMARY OF OPERATIONS

Primary stations occupied	6
Primary stations reoccupied	2
Primary lines observed	40
Lines to supplementary stations observed	6
Lines to lighthouses observed	24
Lines to church spires observed	5
Lines to domes on buildings observed	2
Horizontal angles measured	65
Vertical angles measured	71
Traverse angles measured	12
Traverse lines chained	4,522′
Vista opened 20 feet wide	1,000′

In addition to the above all stations were tied in to lot corners or road intersections and a description prepared in each case.

DIRECTION MEASUREMENT IN NOVA SCOTIA

J. E. R. Ross, Geodetic Engineer, reports as follows on direction measurement in Nova Scotia and Prince Edward Island, during the season of 1920:—

The object of the season's work was to extend the primary triangulation eastward from Truro towards Cape Breton and Prince Edward Island. Enough work was done to establish two stations in Prince Edward Island, but owing to the shortage of necessary towers intersections only were obtained on points in Cape Breton. The observing was done by two parties under Mr. C. H. Brabazon and Mr. L. N. Wadlin, who are reporting to you separately on their respective operations. In all twelve primary and two secondary stations were occupied with the twelve-inch instrument The work in general was delayed by long periods of low visibility caused by forest fires and summer haze. This was especially noticeable on the longer lines connecting stations on opposite coasts. The interior area of the extended triangulation covers an area of 4,000 square miles.

The location of a few well-chosen stations in the reconnaissance close to the coast line afforded an excellent opportunity of obtaining numerous intersections on lighthouses, whose positions should be of great value in the control of charts along this region. The total number of lighthouses with three intersections—or a complete check on their final positions—is twelve. Of these, seven are on the shore of Prince Edward Island and the remainder on the Nova Scotia coast.

A supplementary scheme of five stations based upon one primary and the two secondary points occupied by the large instrument was introduced in the vicinity of New Glasgow and Pictou to connect the work of the Geological Survey used in making a topographical map of the New Glasgow mines area, and also to obtain check readings on three supplementary stations in Pictou. The location of these points will be of use locally; three are in Pictou, two in the near vicinity, and one each at New Glasgow and Trenton. Monumenting of three stations still remains to be done as cement could not be obtained. A six inch Watts instrument with two micrometers, reading to five seconds, was used on this work, and six repetitions made on the angle and also on its explement. The average closure of a triangle was 4·2″. A smaller average closure could easily be obtained by changing the reticule from a single vertical wire to an oblique cross form which would allow more accurate bisections to be made on the signal.

In the above connection the Geological Survey stations Mountville and Fraser Mountain were occupied. These are marked by four-inch gas pipes projecting about three feet above ground and surmounted by bench-mark tablets.

Direction Measurement in Nova Scotia and Prince Edward Island

L. N. Wadlin, Geodetic Engineer, submits the following report.

On leaving Ottawa May 23 the party proceeded to Truro, N.S., where the outfit had been stored the previous season.

Nuttby Mountain was the first station to be occupied and this place was made a rendezvous from which the lightkeepers could be placed at their several stations.

The efficiency of the motor-truck was here clearly demonstrated by the speed with which the lightkeepers were moved to their several stations without relying on trains or local conveyances.

On completion of the work at Nuttby we moved to Pugwash. Here, in addition to the regular stations, readings were taken on a large number of lighthouses both on the Nova Scotia shore and that of Prince Edward Island.

This work of cutting in lighthouses was continued all the season and when the results of this party are combined with those of C. H. Brabazon's party the position of the principal lighthouses both on the north coast of Nova Scotia and the east coast of Prince Edward Island will be definitely known. This work should very materially assist the Hydrographic Survey in its work in this locality.

After finishing at Pugwash we moved to Cape John, which station was soon completed, as were also the two secondary stations Green Hill and Trenton.

At Green Hill in addition to the regular work the station was connected by a traverse line to the work done by the Geological Survey in the vicinity of New Glasgow and Trenton. Several churches in the towns of Pictou and Trenton were cut in both from Green Hill and Trenton.

The next stations in order were Blue Mountain, Eigg Mountain, and McDonald Mountain, and on the completion of the last named operations for the season were closed and the outfit stored at Antigonish.

During the summer the work was held up repeatedly by hazy and foggy weather. It might be of interest to note that in not a single case was delay occasioned in moving. In every case on completion of a station the party moved the following day being always set up and ready for work on the evening of that day.

PRECISE LEVELLING IN 1920

F. B. Reid, Supervisor of Levelling, submits the following progress report upon precise levelling operations during the season of 1920. Five parties were in the field, in charge of Messrs. McMillan, Raley, Rainboth, Sinclair, and Smith.

1. *Levelling by D. McMillan.*—This party left Ottawa on April 28 for Lanigan, Sask., and commenced levelling on May 3. The Canadian Pacific railway was followed from Lanigan southerly through Bulyea to Regina, where the levels were closed on bench-mark 3-D, in the Canadian Pacific station. From Craven, a point about twenty-two miles north of Regina, a connection was made to Lumsden, which is a corresponding distance from Regina on the Prince Albert line of the Canadian National railway. Thus two circuits were developed from the original circuit Regina-Saskatoon Yorkton-Regina.

It is worthy of mention that Mr. McMillan found it necessary to do about twenty-five miles of rerunning east and west of Lanigan, on the Yorkton-Saskatoon line, in order to get stable bench-marks on which to base his new levels. A boulder, an elevator and another building were all found to have changed in elevation since the bench-marks were established in them in 1918. Furthermore, it was observed that they were actually changing during the progress of the check levelling—the frost not being entirely out of the ground at that time. The concrete bench-mark piers, on the other hand, were found to have held their elevations exactly, this being in accord with former experience when rerunning between Regina and Saskatoon.

As the only bench-mark in the village of Lanigan was one of those discovered to be unreliable, a concrete pier was built (on the Yorkton-Saskatoon line) a short distance east of Lanigan in order to supply a reliable bench-mark for the village.

From Regina the levels were continued easterly along the Canadian National railway to close on G. S. Raley's levels at a point three and a half miles east of Kelso, Sask. The last levelling was done on October 19.

2. *Levelling by G. S. Raley.*—This party assembled at Empress, Alta., and commenced levelling on May 11, continuing the line from Bassano which had been carried to a point seventeen miles west of Empress the previous fall. The line was closed on August 13 on bench-mark 126-C, in the Canadian Pacific station, Swift Current. The party then moved to the Canadian National line between Regina and Brandon, on the west end of which Mr. McMillan was working; levels were started three and

a half miles east of Kelso and continued to Brandon, to close on bench-mark 376-C, the connection being effected on October 27.

Finally the party moved to Portage-la-Prairie and initiated a line to follow the Great Northern railway towards the international boundary. Owing to the lateness of the season, however, only about seven miles were levelled out of Portage-la-Prairie and the party was disbanded on November 4.

3. *Levelling by A. J. Rainboth.*—This party left Ottawa on April 29 for Prince Rupert, B.C., and commenced levelling there on May 13; the levels followed the Grand Trunk Pacific railway easterly from Prince Rupert, being started from the Naval Service Department's tidal station. The party was disbanded at New Hazelton, B.C. on September 14.

4. *Levelling by G. E. B. Sinclair.*—This party assembled at Elma, Man., on May 3 and commenced levelling near there the next day. The line extended easterly along the Canadian National railway, being based on bench-mark 19-F, which is at the intersection of the above railway with the main line of the Canadian Pacific. Precise levels along the latter—from Winnipeg to Kenora—were run in 1913, during the progress of which bench-mark 19-F was established. The season's operations for this party were discontinued at Jacobs, Ont., on September 14.

5. *Levelling by N. H. Smith.*—This party left Ottawa on May 4 for Niagara Falls, Ont., and commenced levelling on the eighth at St. Catharines. Levels were extended along the Grand Trunk railway through Merritton to Niagara Falls, Ont., and across the lower steel arch (Grand Trunk) bridge to close on two bench-marks of the United States Coast and Geodetic Survey at Niagara Falls, N.Y. A branch line was run from the lower arch bridge along the Canadian side of the Niagara river and through Queen Victoria park, bench-marks being established in the buildings of the three power companies.

When tying in the old bench-mark at Merritton a change of elevation was noticed so it was thought well to rerun the levels to Welland and Port Colborne and also to Port Dalhousie, in order that there might be no uncertainty regarding the connection between lake Erie and lake Ontario. This rerunning was also extended from Welland Junction to Bridgeburg and four standard bench-mark piers constructed between these points—the original line of levels having been insufficiently provided with bench-marks. Two or three of the bench-marks south of Merritton were found to have changed in elevation, this quite likely being due to the heavy blasting operations during the construction of the new Welland canal. In addition one or more errors must have crept into the original work (which was done late in the season and under very unfavourable weather conditions), the newly determined elevation at Bridgeburg being 0.147 foot lower than formerly.

The next undertaking was to make a connection through the Detroit River tunnel of the Michigan Central railroad between our previously established levels at Windsor, Ont., and the levels of the United States Coast and Geodetic Survey and United States Lake Survey at Detroit, Mich. At the time our levels were first established in Windsor the tunnel was not available and consequently there was no means of connecting the levels across the Detroit river. In the course of the operations this year eight new bench-marks were established—in Walkerville, Windsor, and Detroit.

Precise levelling in connection with the mapping of the city of London was the next duty. This was of smaller extent but of much the same nature as the levelling in the Vancouver district done in 1919. In the first place a circuit of levels was extended around the outskirts of the city, intersecting at two points the main line of levels from Toronto to Windsor which cuts practically through the centre of London. The length of this outer circuit was 21 miles and it was double-levelled, i.e., run both forward and backward, in accordance with standard practice. It was then divided up by eight short lines, partly of single and partly double levelling. In

all, 7·4 miles of single levelling was done and 33·6 miles of double. Bench-marks established were of three kinds; first, the standard bench-marks of the Geodetic Survey, consisting of copper bolts placed either horizontally in the walls of buildings or vertically in concrete piers constructed for the purpose; second, "iron-pipe" bench-marks; third, copper bolts set vertically in masonry or concrete surfaces.

The bench-marks of the first type were numbered in one of the regular series of the Geodetic Survey, those of the second and third types were numbered in a separate "City of London" series. The "iron-pipe" bench-marks consist of a section of two-inch galvanized iron pipe six feet six inches in length split at the lower end for about eighteen inches and the two halves spread apart. A hole about six feet in depth was made with the aid of a post-hole auger and the split end of the pipe bedded in a mass of concrete; the top of the pipe—projecting six inches or so above ground—was finished with a cast iron cap, upon which the elevation was taken. Nineteen of the standard bench-marks were established and seventy-six of the "City of London" bench-marks. This provides an ample number of permanent points for checking the detail levelling in all parts of the city. The precise level net of London is shown in green on the progress map of the survey of London inside the back cover.

The London levelling was begun on June 23 and completed on August 4, after which the party moved to Tweed, Ont., and spent the balance of the season levelling north from there along the Canadian National railway. At the close of the season, on October 14, the levels had reached York river, 63 miles from Tweed. The uncompleted portion of the line from Lindsay and Howland was also finished through to York river. This line had been discontinued in October, 1919, at a point 26 miles east of Howland.

6. *Summary of Field Work.*—The mileage run by each leveller is shown in the following table, also the percentage of relevelling, the number of standard bench-mark piers built, and the total number of bench-marks established, including piers:—

Leveller	Mileage levelled	Percentage relevelled	Piers built	Total Bench-Marks established
D. McMillan	244 (*a*)	12%	40	55
G. S. Raley	239	11%	53	79
A. J. Rainboth	181	10%	9	67
G. E. B. Sinclair	283	5%	10	102
N. H. Smith	161 (*b*)	6%	19	78
Total	1,108	....	131	381

(*a*) New levelling only. In addition to this 41 miles of rerunning was done—at Lanigan, Regina, etc.
(*b*) New levelling only. In addition to this 43 miles of rerunning was done between Port Dalhousie and Port Colborne and between Welland Junction and Bridgeburg.

Lines levelled in 1920:—

Line	On Railway	Off Railway	Total
Lanigan to 3½ miles east of Kelso, Sask	234·1	9·9	244·0
17 miles west of Empress, Alta., to Swift Current, Sask	135·0	0·6	135·6
3½ miles east of Kelso, Sask., to Brandon, Man	93·3	3·0	96·3
Portage-la-Prairie, Man., southerly	6·2	0·4	6·6
Prince Rupert to New Hazelton, B.C	180·6	0·0	180·6
Rennie, Man., to Jacobs, Ont	283·5	0·0	283·5
St. Catharines, Ont., to Niagara Falls, N.Y	12·2	7·0	19·2
Windsor, Ont., to Detroit, Mich	6·8	6·8	13·6
London District Lines, Ont	11·9	29·1	41·0
Tweed to York River, Ont	62·6	0·0	62·6
26 miles east of Howland to York River, Ont	25·0	0·0	25·0
Total	1,051·2	56·8	1,108·0

As mentioned on a previous page, 14,031 miles of levelling have been completed to date. This mileage is distributed among the provinces as follows:—

Province	Previous to 1920	1920	Total
Ontario	3,678	424	4,102
Saskatchewan	1,407	386	1,793
Quebec	1,776	0	1,776
British Columbia	1,600	181	1,781
Alberta	1,464	17	1,481
Manitoba	882	100	982
New Brunswick	864	0	864
Nova Scotia	705	0	705
Yukon Territory	458	0	458
Minnesota, U.S.A.	89	0	89
Total	12,923	1,108	14,031

It is distributed among the railways as follows:—

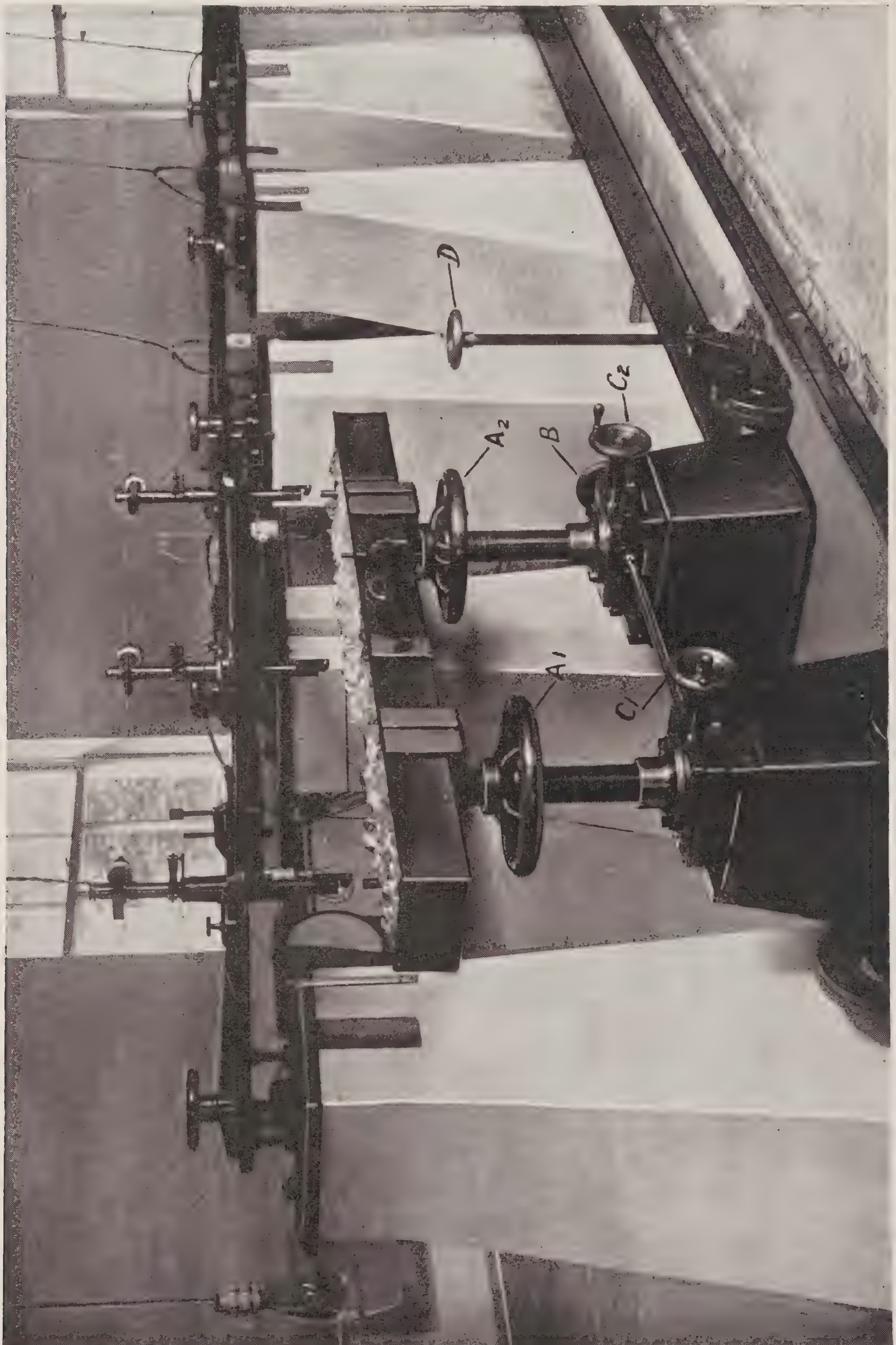
	Previous to 1920	1920	Total
Canadian National-Grand Trunk	5,871	804	6,675
Canadian Pacific	5,193	248	5,441
Algoma Central	219	0	219
Great Northern	170	6	176
Dominion Atlantic	146	0	146
Quebec Central	109	0	109
White Pass and Yukon	91	0	91
Temiscouata	82	0	82
Ottawa and New York	55	0	55
Pere Marquette	55	0	55
Maine Central	36	0	36
Boston and Maine	34	0	34
Napierville Junction	28	0	28
British Columbia Electric	28	0	28
Quebec Ry. Light & Power Co	25	0	25
Pacific Great Eastern	9	0	9
Michigan Central	0	3	3
London & Port Stanley	0	2	2
Highways	772	45	817
Total	12,923	1,108	14,031

REPORT OF F. A. McDIARMID ON WORK FOR 1920-21

1. Standards.
2. Laplace Determinations.
3. Mapping of Arctic Explorations of Stefansson's Arctic Expedition.

(1) STANDARDS

Bars and Tapes.—During the past year there have been added to the equipment of the Standards building five additional microscopes and a separate car to carry the metre trough and its load of ice and bars. Both the microscopes and the car have added a great deal to the accuracy obtainable in securing the lengths of the invar base line tapes, and also to the ease and rapidity of the observations. Formerly there were but six microscopes, two of which are mounted permanently on the end piers of the fifty-metre comparator, while the other four were used on the intermediate piers, and as the bar was moved along the comparator the microscopes were transferred from the rear. A transit mounted over the fiducial point at one end of



Standards Building. Separate car carrying ice laden metre trough and metre bar

the comparator was used to put the microscopes in line, and although the positions of the microscopes on the arms are always carefully marked, yet it is difficult once having loosened the clamp to replace the microscope in its original position. The five new microscopes permit of one on each pier, and when the microscopes have been once alined by the transit they are left solidly mounted until the whole series of observations has been completed. The values of a turn of the micrometer screws were determined from observations on the graduations of one of the metre bars.

In determining the length of the five-metre bar from any of the one-metre bars, or in intercomparing the three one-metre bars, a trough holding the one-metre bar with its ice solution was placed on top of the five-metre ice trough. This had two important disadvantages, first the extra weight of the one-metre trough with its load of ice caused a flexure in the five-metre bar, and changed its length by several microns; second it was very difficult to properly adjust the metre bar under the microscopes with only the adjustments provided on the five-metre bar. The new car entirely eliminates all these difficulties. The accompanying photograph shows the car with its different adjustments. The trough is raised or lowered by means of the spiral screws A_1 and A_2, moved longitudinally by means of the screw B, and transversely by the screws C_1 and C_2. The car is clamped to the rail by the clamp D. When determining the length of the five-metre bar from the metre bar, the latter is mounted on two cross supports placed at the twenty-fifth and seventy-fifth centimetre marks. In comparing the two metre-bars, they are placed side by side in the trough. The supports are so arranged that the bars are separated by about one-half inch, so that the melting ice can be worked in close to the bars.

The work done in the standards division of the Survey comprised the intercomparisons of the three one-metre bars Nos. 10239, 10241 and 10241A; standardizing the five fifty-metre invar base line tapes; the one hundred- and two-hundred-foot tapes used in city triangulation work in London and Montreal; graduating and standardizing the precise level rods of the Geodetic Survey.

In intercomparing the three one-metre bars the same program was followed as formerly. Bars Nos. 10239 and 10241A were first compared, then Nos. 10239 and 10241 and finally Nos 10241 and 10241A.

The results from these observations from year to year are of interest in that they give some idea of the constancy of the standards of the Geodetic Survey of Canada.

In last years report there was given a detailed account of the comparisons of the nickel bar No. 10239 with the standard bars of the Bureau of Standards at Washington, D.C., also the results of the intercomparisons of the three bars Nos. 10239, 10241 and 10241A of the Geodetic Survey. The length of bar No. 10239 as given by Washington is $1^m + 25.8$ microns. The deduced lengths of bars Nos. 10241 and 10241A were $1^m—19.5$ microns and $1^m—24.2$ microns respectively. Assuming the length of the nickel bar No. 10239 to have remained at $1^m + 25.8$, the 1920 intercomparisons of these three bars make the lengths of bars No. 10241 and No. 10241A, $1^m—20.5$ microns and $1^m—24.6$ microns respectively. The errors of observations in the different observations are nearly the same, viz., ±, 20 microns. These results show that the three bars are retaining a constant length to one another, and the comparisons made at Washington in 1919 show that the length of the nickel bar No. 10239 has changed almost imperceptibly since it was obtained by the Geodetic Survey several years ago.

The five fifty-metre tapes of the Survey were standardized following the usual program as follows: length of five-metre bar from standard metre bar No. 10239, length of fifty-metre comparator from five-metre bar, length of fifty-metre reference tape No. 4252 from fifty-metre comparator, and length of the field tapes from the reference tape. The addition of the new microscopes makes it possible to step up from the metre bar to the reference tape in a single day. In the morning, say from nine to twelve, determinations of the reference tape can be secured. The whole secret

of success in this work is, first to be sure that the bars in the solution of melting ice are at zero centigrade, and second having secured the length of the five-metre bar, all speed should be employed to get the length of the comparator and the length of the reference tape. Fifteen minutes is generally sufficient time to move the five-metre bar along the comparator and obtain the length of the latter.

In the table below are given the lengths of the five invar fifty-metre tapes in the fall of 1919 and in 1920.

Date	Lengths of—				
	4252	3139	3140	3141	13814
	Metres	Metres	Metres	Metres	Metres
October 1919	50·000412	49·999420	50·000056	50·000300	50·000300
July .. 1920	50·000412	49·999344	50·000025	50·000258	50·000292

This table shows that the two reference tapes Nos. 4252 and 13814 kept their lengths almost perfectly, but that the other three, the field tapes, shortened by amounts varying from 31 microns to 86 microns. During the interval between these determinations the five tapes were hanging on a double catenary from the ceiling of the comparator room. The fact that some of these tapes changed their lengths while others did not, points clearly to the need of frequent standardizing of our base line tapes.

The one hundred- and two-hundred-foot tapes used in the city triangulation work in Montreal and London were standarized both on the flat and supported at fifty-foot intervals. The method of standardizing hundred-foot tapes is given in last year's report. The length of the two-hundred-foot tapes is derived from a comparison with the hundred-foot tape. A base line two hundred feet long is laid down with the hundred-foot tape and the two-hundred-foot tapes are compared with this base line, a tension of fifteen kilogrammes put on by a spring balance was used on these tapes.

The hundred-foot tape No. 51 was standardized June 24, 1920, both on the flat and supported at fifty-foot intervals, its length at 16°.5 C. was found to be as follows: on flat 100·03055 feet; supported at fifty-foot intervals, 100·02942 feet. No. 52, a two-hundred-foot steel tape under a tension of 15 kilogrammes applied with a spring balance gave lengths at 16°.5 C. as follows:

On flat 200.06018 feet.

Supported at fifty-foot intervals 200.05405 feet.

In November after being used in London during the summer No. 52 was again compared with No. 51. No. 51 was not used at all during the summer, and on account of the lateness of the season and the lack of ice the length of No. 51 as given in June was considered constant. The length of No. 52 in November was the following:

On flat 200.07029 feet.

Supported at fifty-foot intervals 200.06403 feet.

These results indicate that this tape had increased in length during the summer .01004 feet. The tape had been pulled over sidewalks and pavements, and this probably accounts for the lengthening.

Another two-hundred-foot tape used in Montreal city triangulation measured on the flat gave a length of 200·03141 feet at 16°·5 C.

Graduation of Precise Level Rods.—The precise level rods of the Geodetic Survey were all standardized at the end of the season. An aluminum bracket was made so that microscopes could be mounted at one- two- and three-foot intervals. One foot is very nearly 91·5 cm. and the several microscopes are so mounted that their zeroes correspond nearly to pointings on 0, 30·5, 61 and 91·5 cm. graduations on the metre bar. The observations were made when the temperature of the atmosphere was nearly 0° C, the invar metre bar being used without the ice solution

Extended tabular statements are not usually of popular interest, but as the behaviour of these level rods during the year has a very considerable bearing on the future use of wooden rods on precise level work, the results of these observations cannot fail to be of value.

The following table gives the corrections to be applied to the several graduation marks on the different rods. The negative sign indicates that the distance on the rod is too short, and positive sign that the distance is too great.

Rod	Corrections in inches at—					
	1 foot	3 feet	5 feet	6 feet	7 feet	9 feet
7	—·0074	—·0107	—·0090	....	—·0115	—·0124
8	—·0229	—·0252	—·0298	....	—·0319	—·0330
15	—·0071	—·0071	—·0103	....	—·0116	—·0128
16	—·0110	—·0124	—·0223	....	—·0273	—·0358
11	....	—·0094	....	—·0089	....	—·0076
12	....	—·0005	....	·0013	....	·0050
13	....	—·0129	....	—·0276	....	—·0427
14	....	—·0127	....	—·0280	....	—·0434
5	....	·0036	....	·0053	....	·0125
6	....	·0010	....	·0065	....	·0262
1	....	—·0241	....	—·0368	....	—·0660
2	....	—·0331	....	—·0331	....	—·0394

These rods had all been graduated by the Inland Revenue Department and the changes tabulated above have arisen from the effects of temperature and climate conditions. A glance at the results will show that the changes occur nearly proportionally all along the several rods, and this very important question regarding changes in lengths of precise level rods is now engaging attention. These rods are of wood, boiled in paraffin, and the effect of the climate conditions during the course of the summer is a problem that is vital to extreme accuracy and which will be the object of special research during the coming summer.

BASE LINES

In connection with the triangulation on the lower St. Lawrence, the reconnaissance for a base line was made on Anticosti island. This island is about one hundred and twenty miles long, and fifteen to thirty miles wide. It lies approximately northwest and southeast.

The elevation at the centre of the island is about three hundred and fifty feet above the sea, and this elevation is carried a considerable distance from the northwest end of the island. Except for small patches of land which have been cleared by the Anticosti Island Agency the whole island is covered with a dense forest, the trees are not large, very few exceeding eighteen inches in diameter and not more than fifty to sixty feet in height. Some years ago when the island was bought by Mr. Menier, a settlement was established near the southwest corner at Ellis Bay. Here a well ordered town was built, with its stores, electric plant, water system, lumber and pulp mills, etc. A railroad was built from Ellis Bay into the interior of the island, a distance of nearly thirty miles. Lumbering operations were carried on extensively and a strip about twenty-five miles long and from six to eight miles wide has been cleared. Of late years on account of the scarcity of labour these operations have been closed down. Some farming has also been done on the parts of the island cleared of the timber.

On a portion of the cleared country near the height of land a splendid site for a geodetic base line was located. A year or two ago fire burnt over this part of the island and cleaned up the brush and refuse left after the lumber operations which made it easy to cover the country. Also the railroad from Ellis Bay made transportation a matter of little difficulty. A base line nearly eight miles in length was

located; the east end of the base is near mile post eighteen on the railroad from Ellis Bay and the west end on a hill north from mile post ten. There is less than half a mile of clearing to be done on the whole line, and timber for posts can be found along the base line. The grades are good and no trouble should be encountered in measuring. The preparation and measuring of this base should take not more than a couple of months. It is hoped to carry on this particular work during the summer of 1921.

(2) LAPLACE DETERMINATIONS

One triangulation station was occupied as a Laplace station during the past year. Cap Chat, on the Lower St. Lawrence, proved especially suitable, as it was within easy reach of the telegraph line to Gaspé, and also near a main highway; and no difficulty was experienced in getting instruments, cement and gravel carried to the top of the hill.

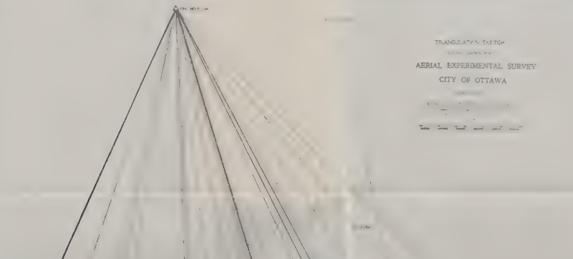
Cap Chat triangulation station is on a cliff about five hundred feet above Cap Chat lighthouse. It commands a view of the St. Lawrence river, both above and below this point. The line from Cap Chat to the station at Mechin was used as an azimuth line. In addition to the observations for the longitude and azimuth, the latitude was also observed. The results of these observations are not yet deduced.

(3) CANADIAN ARCTIC EXPEDITION

The reduction of the observations made by the Canadian Arctic Expedition during the years 1914 to 1918 has occupied a great deal of time. Over three hundred determinations of geographical positions (longitude and latitude) and a large number of azimuth results have been used in correcting the existing maps and mapping new lands discovered by the parties under Mr. V. Stefansson, the commander of the expedition. A detailed account of the methods and a summary of the results together with maps will be given in a subsequent report.

INDEX


LEVEL NET
OF
EASTERN CANADA
Levelling by Geodetic Survey of Canada shown by
Tide Survey Bench Marks indicated thus
Points where Canadian and American levelling


AERIAL EXPERIMENTAL SURVEY
CITY OF OTTAWA

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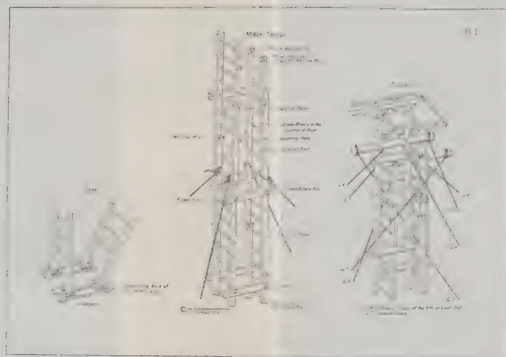

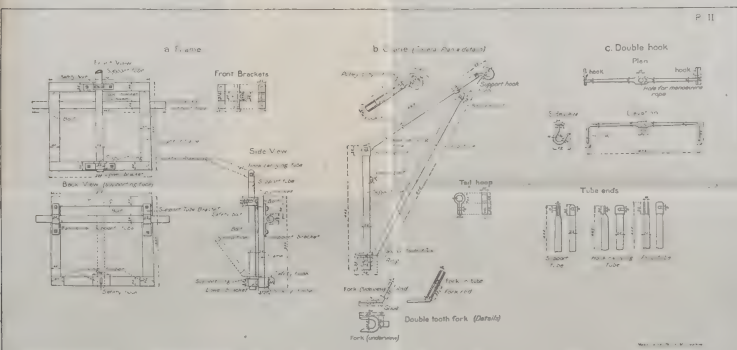

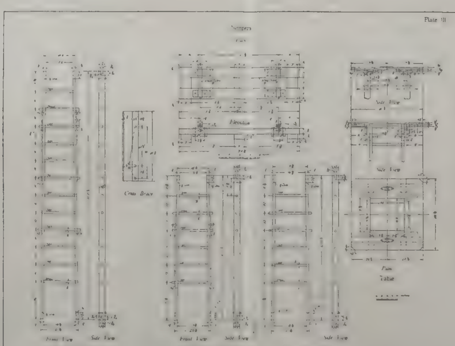

Details of Dismountable Ladder (see page 43)


Department of the Interior
GEODETIC SURVEY OF CANADA
MAP SHOWING
PROGRESS OF TRIANGULATION
AND
PRECISE LEVELLING
TO MARCH 31, 1921
NOEL OGILVIE, Superintendent
LEGEND
TRIANGULATION COMPLETED
TRIANGULATION BEGUN
PRECISE LEVELLING
HUDSON BAY
MANITOBA
SASKATCHEWAN
ALBERTA
BRITISH COLUMBIA
ONTARIO
QUEBEC
NEW BRUNSWICK
NOVA SCOTIA
LAKE SUPERIOR
LAKE HURON
LAKE MICHIGAN
LAKE ERIE
PACIFIC OCEAN
VANCOUVER
NORTH DAKOTA
SOUTH DAKOTA
Victoria Island
James Bay
LITHOGRAPHED AT THE SURVEYOR GENERAL'S OFFICE, OTTAWA, CANADA


CITY OF LONDON
ONTARIO
PROGRESS MAP
OF
THE SURVEY OF LONDON
by the
GEODETIC SURVEY OF CANADA
1920
SCALE
1000
2000
3000
4000
5000 Feet
1 Mile
Triangulation Net
Precise Level Net
Secondary Level Bench-marks
Traverse Stations
Topography Surveyed
Contours Surveyed
City Limit
Outlines of Projected Map Sheets
Outlines of Published Map Sheets
Geodetic North
ORPHANAGE
CEMETERY
CURRY
TRAFALGAR
WHARNCLIFFE
ODELL
ST. MARY
MT. PLEASANT
TO BIDDULPH
TO GIRVAN
TO NISSOURI
TO SPRINGBANK
TO WESTMINSTER

PUBLICATIONS OF THE GEODETIC SURVEY OF CANADA

Publication No. 1—Precise Levelling—Certain Lines in Quebec, Ontario and British Columbia.

Publication No. 2—Adjustment of Geodetic Triangulation in the Provinces of Ontario and Quebec.

Publication No. 3—Determination of the Lengths of Invar Base Line Tapes from Standard Nickel Bar No. 10239.

Publication No. 4—Precise Levelling—Certain Lines in Ontario and Quebec.

Publication No. 5—Field Instructions to Geodetic Engineers in charge of Direction Measurement on Primary Triangulations.

Appendix No. 1 of Publication No. 5—Instructions to Lightkeepers on Primary Triangulation.

Publication No. 6—Precise Levelling—Certain Lines in Manitoba and Saskatchewan.

Publication No. 7—Geodetic Position Evaluation.

Publication No. 8—Field Instructions for Precise Levelling.

Annual Report of the Superintendent of the Geodetic Survey of Canada for the Fiscal Year ending March 31, 1918.

Annual Report of the Superintendent of the Geodetic Survey of Canada for the Fiscal year ending March 31, 1919.

Annual Report of the Superintendent of the Geodetic Survey of Canada for the Fiscal year ending March 31, 1920.